the excellence of his primary education and by the natural zeal which he possesses for the acquisition of knowledge is certain to rise to the opportunity now to be placed in his way. It is unnecessary to institute comparisons, but it may be safely said that this Highland school will have raw material to deal with of which many an English rural district might well be envious.

RESIN-TAPPING.

CRUDE resin is almost always obtained from pines of various species, *e.g.* *Pinus Pinaster* or *P. maritima* in Europe, *P. palustris, P. Taeda* and *P. australis* in America, and *P. longifolia, P. excelsa*, &c., in India. It may also be obtained from other Conifers

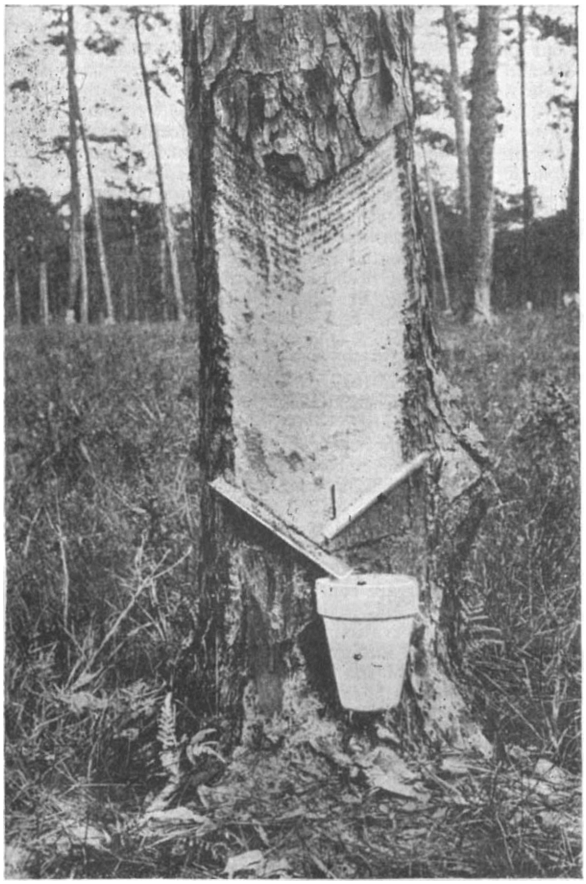

FIG. 1.—Cup and Gutters used in collecting Crude Turpentine.

(spruce, larch, &c.), and even from some Dicotyledons. The universal practice is to cut through the cortex and to allow the crude viscous liquid oleo-resin to drip into some form of receptacle, *e.g.* a hole in the sandy soil, or an excavated "box" in the foot of the bole, or a metal or earthenware "pot" hung on to the tree.

From the crude resin thus obtained, numerous other products are derived by means of distillation, &c. Among these spirits or oil of turpentine, colophany (rosin), pitch and tar are the most important, and the quantities of these substances required annually for naval purposes, for making varnishes, sealing-wax, &c., are so great that the resin industry is a large and lucrative one.

There are certain limits to the working of a pine-tree as a resin-factory which increase the expense of production so considerably that it has long been the practice in America recklessly to abandon a tract worked for resin and push forward into newer regions. These limits of production depend especially on the fact that cutting large holes in the basal parts of the bole of a tree is bound to result in disaster sooner or later; and since the American plan systematically pursued has been that of "boxing"—*i.e.* cutting large holes in the wood below, into which the resin from the cut and scarified cortex should slowly drain—the inevitable result has been the wholesale destruction of the trees by means of rot-fungi, wind throwing, ground fires, &c.

This state of affairs has naturally driven the authorities to seek for some better methods of extracting the resin, and in a recent publication [1] Dr. Hertz brings forward the results of a very complete set of experiments designed to compare the yield and value of the resin obtained by the old "boxing" method, and that obtained by a modification of the European systems.

The latter consists in allowing the resin from the periodically scarified cortex and young wood to drain down into two slanting spouts of thin tin, which direct it into a pot hung properly beneath. The advantages claimed for the improved system are, a longer life of the tapped tree, a greater yield of resin all the time, less waste in catching the resin, diminished evaporation of volatile products, and less dirt and discoloration as the liquid flows over the face exposed, as well as other and minor points.

These matters, expressed in terms of money value, are given in a series of tables, from which the following is the extract only:—

Half crop.	From dip.	From scrape.	Total.	Excess.
Second year.	Dollars.	Dollars.	Dollars.	Dollars.
Cups	266.34	49.25	315.59	144.13
Boxes	104.51	66.95	171.46	—
Third year.				
Cups	171.27	27.44	198.71	132.65
Boxes	39.49	26.57	66.06	—
Fourth year.				
Cups	167.33	29.23	196.56	132.56
Boxes	36.09	27.91	60.00	—

The bulletin is admirably written, and affords an excellent example of what may be done by a properly trained expert in learning the methods of an old industry practised in another country, improving and adapting them to the wants of his own locality, and, above all, in demonstrating his points so convincingly by means of experiments that the most prejudiced of his workmen becomes reconciled to the innovations.

The illustrations, of which we select one, are well chosen, sufficient, and admirably executed.

THE SOUTHPORT MEETING OF THE BRITISH ASSOCIATION.

THE Southport meeting of the British Association was concluded as we went to press last week. At the meeting of the General Committee on Wednesday, September 16, the resolutions sent forward by the Committee of Recommendations, and printed in last week's NATURE, were adopted. In addition, the two following resolutions were carried:—

(1) That the systematic investigation of the upper currents of the atmosphere by means of kites or

[1] "A New Method of Turpentine Orcharding," by Dr. C. H. Hertz. U.S. Department of Agriculture, *Bull.* xl., 1903.

balloons is of great importance in meteorology, and that the Council should take such steps as they might think fit to urge upon the Treasury the importance of providing the Meteorological Council with the funds necessary for the purpose. (2) That the Sectional Committees be continued in existence until the appointment of the Sectional Committees for the succeeding year, on being summoned by the president of the committee or by the Council, and that they be authorised to bring to the notice of the Council in the interval between the annual meetings any matter which might be desired in the interest of the several sections.

At the concluding meeting, held on the same day, resolutions were proposed and unanimously carried conveying thanks to the Mayor and Corporation, Local Committee, and other bodies who had helped to make the meeting a success by their personal services and generous hospitality. Appreciation of the handsome way in which the visitors were treated was also expressed at a dinner which the Mayor of Southport, Mr. T. T. L. Scarisbrick, gave on Wednesday evening, when a distinguished company was entertained by him at Greaves Hall, Banks, to meet Sir Norman Lockyer and Prof. E. Mascart, president of the International Meteorological Committee.

SECTION E.

GEOGRAPHY.

OPENING ADDRESS BY CAPTAIN ETTRICK W. CREAK, C.B., R.N., F.R.S., PRESIDENT OF THE SECTION.

OF the six distinguished naval officers who have previously presided over this Section, four were Arctic explorers; and therefore, possessing personal experience in Arctic regions, they naturally gave prominence to the deeply interesting subject of the past and future of Arctic discovery in their addresses, whilst not forgetting other matters relating to the geography of the sea. The remaining officers, from their immediate connection with all that relates to the physical condition of the ocean, in its widest sense, coupled with the great importance of giving the fruits of their knowledge to the world, took that subject as their principal theme.

Valuable as are contributions to our knowledge of the physics of the ocean to the world in general, and especially to the mariner and water-borne landsman, I propose to take a different course, and bring to your notice the subject of Terrestrial Magnetism in its relation to Geography. In doing so, I shall endeavour to show that much may be done by the traveller on land and the seaman at sea in helping to fathom the mysteries connected with the behaviour of the freely suspended magnetic needle, as it is carried about over that great magnet, the Earth, by observations in different regions, and even in limited areas.

I would, however, pause a moment to call attention to the presence of several distinguished meteorologists at this meeting, who will surely attract many to the consideration of matters connected with the important science of meteorology, which already occupies considerable attention from travellers. I feel sure, therefore, that geographers will be glad to accord a hearty welcome to the members of the International Meteorological Congress now assembled in this town, and especially to the foreign visitors who honour us by their presence.

Someone may ask, What has Terrestrial Magnetism to do with Geography? I reply, excellent lectures on that subject of growing importance have been given under the direct auspices of the Royal Geographical Society; one in 1878 by the late Captain Sir Frederick Evans, and another in 1897 by Sir Arthur Rücker. And I would here quote the opinion of Dr. Mill when defining geography, in my support: "Geography is the science which deals with the forms of the Earth's crust, and with the influence which these forms exercise on the distribution of other phenomena."

We know now that the normal distribution of the Earth's magnetism for any epoch is in many localities seriously affected accordingly as the nature of the country surveyed be mountainous, or generally a plain, in the form of islands (or mountains standing out of the sea), and from land under the sea. There is also reason to suspect that the magnetism of that portion of the earth covered by the oceans differs in intensity from that of the dry land we inhabit. A connection between the disturbances of the earth's crust in earthquakes and disturbances of the magnetic needle also seems to exist, although the evidence on this point is not conclusive.

Magnetic Surveys.

Previously to the year 1880 there were two periods of exceptional activity on the part of contributors to our knowledge of the earth's magnetism, during which the scientific sailor in his ship on the trackless ocean combined with his brethren on land in making a magnetic survey of the globe.

The first period was that of 1843–49, during which not only were fixed observatories established at Toronto, St. Helena, Capetown, and Hobart for hourly observations of the movements of the magnetic needle, but, to use Sabine's words, "that great national undertaking, the Magnetic Survey of the South Polar Regions of the Globe," the forerunner of our present Antarctic Expedition, was accomplished by Ross and his companions almost entirely at sea.

This Antarctic survey was carried out during the years 1840–45, and the results given to the world as soon as possible by Sabine. The results afterwards formed a valuable contribution when constructing his maps of equal lines of Magnetic Declination, Inclination, and Intensity for the whole world, a great work for the completion of which Sabine employed every available observation made up to the year 1870, whether on land or at sea.

Readers of these contributions cannot fail to be struck with the great number of observations made by such travellers as Hansteen and Due, Erman and Wrangel, extending from Western Europe to far into Siberia.

The second period was that of 1870–80, during which not only was there much activity amongst observers on land, but that expedition so fruitful to science, the voyage of H.M.S. *Challenger*, took place. During the years 1872–76 we find the sailor in the *Challenger* doing most valuable work in carrying out a magnetic survey of certain portions of the great oceans, valuable not only for needful uses in making charts for the seaman, but also as a contribution to magnetic science.

Prior to this expedition very little was known from observation of the distribution of Terrestrial Magnetism in the central regions of the North and South Pacific Oceans, and Sabine's charts are consequently defective there.

Combining the *Challenger* magnetical results with those of all available observations made by others of H.M. ships, and by colonial and foreign Governments, I was enabled to compile the charts of the magnetic elements for the epoch 1880, which were published in the report of the scientific results of H.M.S. *Challenger*. I will venture to say that these charts give a fairly accurate representation of the normal distribution of the earth's magnetism between parallels of 70° N. and 40° S. Beyond these limits, either northward or southward, there is a degree of uncertainty about the value of the lines of equal value, especially in the Southern regions, an uncertainty which we have reason to hope will be dissipated when we know the full results obtained by Captain Scott and the gallant band he commands, for as yet we have to be content with some eddies of the full tide of his success.

Until the *Discovery* was built, the *Challenger* was the last vessel specially selected with the view of obtaining magnetic observations at sea, so that for several years past results obtained on land have been our mainstay. Thus, elaborate magnetic surveys with fruitful results have been carried out in recent years in the British Isles by Rücker and Thorpe. France, Germany, Holland, and some smaller districts in Europe have also been carefully surveyed, and British India partially so, by Messrs. Schlagintweit in 1857–58. The latter country is being again magnetically surveyed under the auspices of the Indian Government.

On the American continent the Coast and Geodetic survey of the vast territories comprised in the United States, which has been so many years in progress, has been accompanied by an extended magnetic survey during the last fifty-two years, which is now under the able direction of Dr. L. A. Bauer. Resulting from this some excellent charts of the magnetic declination in the United States have been pub-

lished from time to time; and the last, for the epoch 1902, is based upon 8000 observations.

There are other contributions to terrestrial magnetism for positions on various coasts from the surveying service of the Royal Navy, and our ships of war are constantly assisting with their quota to the magnetic declination, or variation, as sailors prefer to call it; and wisely so, I trow, for have they not the declination of the sun and other heavenly bodies constantly in use in the computation of their ship's position?

This work of the Royal Navy and the Indian Marine is one of great importance, both in the interests of practical navigation and of science; for besides the equipment of instruments for absolute determinations of the declination, dip, and horizontal force supplied to certain of our surveying-ships, every seagoing vessel in the service carries a landing compass, specially tested, by means of which the declination can be observed with considerable accuracy on land.

Although observers of many other objects may still speak of their "heritage the sea" as a mine of wealth waiting for them to explore, unfortunately for magnetic observations we can no longer say "the hollow oak our palace is," for wood has been everywhere replaced by iron or steel in our ships, to the destruction of accurate observations of dip and force on board of them. Experience, however, has shown that very useful results, as regards the declination, can be obtained every time a ship is "swung," either for that purpose alone, or in the ordinary course of ascertaining the errors of the compass due to the iron or steel of the ship.

As an example of this method, the cruise of the training squadron to Spitsbergen and Norway in 1895 may be cited, when several most useful observations were made at sea in regions but seldom visited. Again, only this year a squadron of our ships, cruising together near Madagascar, separated to a distance of a mile apart and "swung" to ascertain the declination.

I would here note that all the magnetic observations made by the officers of H.M. ships during the years 1890–1900 have been published in a convenient form by the Hydrographic Department of the Admiralty.

The fact remains, however, that a great portion of the world, other than the coasts, continues unknown to the searching action of the magnetic needle, whilst the two-thirds of the globe covered by water is still worse off. Amongst other regions I would specify Africa, which, apart from the coasts, Cape Colony, and the Nile valley to lat. $5\frac{1}{2}°$ N., is absolutely a new field for the observer.

Moreover, the elaborate surveys I have mentioned show how much the results depend upon the nature of the locality. I am therefore convinced that travellers on land, provided with a proper equipment of instruments for conducting a land survey of the strange countries which they may visit, and mapping the same correctly, can, with a small addition to the weight they have to carry, make a valuable contribution to our knowledge of terrestrial magnetism, commencing with observations at their principal stations and filling in the intermediate space with as many others as circumstances will permit.

The Antarctic Expedition.

Of the magnetic work of our Antarctic expedition we know that since the *Discovery* entered the pack—and, so far as terrestrial magnetism is concerned, upon the most important part of that work—every opportunity has been seized for making observations.

Lyttelton, New Zealand (where there is now a regular fixed magnetic observatory), was made the primary southern base-station of the expedition; the winter quarters of the *Discovery*, the secondary southern base-station. Before settling down in winter quarters, magnetic observations were made on board the ship during the cruise to and from the most easterly position attained off King Edward VII Land in lat. 76° S., long. $152\frac{1}{2}°$ W., and she was successfully swung off Cape Crozier to ascertain the disturbing effects of the iron upon the compasses and dip and force instruments mounted in the ship's observatory.

As a ship fitted to meet the most stormy seas and to buffet with the ice, the *Discovery* has been a great success. Let me add another tribute to her value. From Spithead until she reached New Zealand but small corrections were required for reducing the observations made on board. The experience of Ross's Antarctic expedition had, however, taught the lesson that two wood-built ships, the *Erebus* and *Terror*, with but some 3° to 4° of deviation of the compass at Simon's Bay, South Africa, found as much as 56° of deviation at their position farthest south, an amount almost prohibitory of good results being obtained on board.

How fared the *Discovery*? I have been told by Lieutenant Shackleton—for the cause of whose return to England we must all feel great sympathy—that a maximum of only 11° of deviation was observed at her most southerly position. From this we may look forward hopefully to magnetic results of a value hitherto unattained in those regions.

At winter quarters, besides the monthly absolute observations of the magnetic elements, the Eschenhagen variometers or self-registering instruments for continuously recording the changes in the declination, horizontal force, and vertical force were established, and in good working order at the time appointed for commencing the year's observations.

I may here remind you that some time previously to the departure of the British and German Antarctic expeditions, a scheme of co-operation had been established between them, according to which observations of exactly the same nature, with the same form of variometers, were to be carried out at their respective winter quarters during a whole year, commencing March 1, 1902. Besides the continuous observations with the variometers, regular term-days and term-hours were agreed upon for obtaining special observations with them at the same moment of Greenwich mean time. Both expeditions have successfully completed this part of their intended work.

To co-operate in like manner with these far southern stations, the Argentine Government sent a special party of observers to Staten Island, near Cape Horn, and the Germans another to Kerguelen Land, whilst New Zealand entered heartily into the work. In addition, similar observations were arranged to be made in certain British and colonial observatories, which include Kew, Falmouth, Bombay, Mauritius, and Melbourne; also in German and other foreign observatories.

We have all read thrilling accounts of the journeys of the several travelling parties which set out from the *Discovery*, and of the imminent dangers to life they encountered and how they happily escaped them except one brave fellow named Vince, who disappeared over one of those mighty ice-cliffs, upon which all Antarctic voyagers descant, into the sea. In spite of all this there is a record of magnetic observations taken on these journeys of which only an outline has yet been given. Anticipations of the value of these observations are somewhat clouded when we read in one report that hills "more inland were composed of granite rock, split and broken, as well as weatherworn, into extraordinary shapes. The lower or more outer hills consisted of quartz, &c., with basaltic dykes cutting through them." Consequently, we have to fear the effects of local magnetic disturbances of the needle in the land observations, whilst buoyed up with the hope of obtaining normal results on board the ship.

Judging from some land observations which have been received, it appears that considerable changes have taken place in the values of the magnetic elements in the regions we are considering, but when making comparisons we have to remember the sixty years which have elapsed since Ross's time, and that he had nothing like the advantage of steam for his ships, or of instruments of precision like our present ship *Discovery*. His ships also were, as we have already remarked, much worse magnetically, causing far more serious disturbance of the instruments. Hence the changes we note may not be entirely due to changes in the earth's magnetism.

The observations made by the officers of the *Southern Cross* at Cape Adare in 1899–1900 also contribute to this question of magnetic change.

The Magnetic Poles of the Earth.

I will now refer to those two areas on the globe where the dipping needle stands vertically, known as the magnetic poles. The determination of the exact position of these areas is of great importance to magnetic science, and I will just glance at what is being done to solve the problem.

Let us consider the North Pole first, the approximate position of which we know best from observation. If one were asked to say *exactly* where that pole has been in observ-

ation times, whether it has moved, or where it now is, the answer must be "I do not know." It is true that Ross in 1831, by a single observation, considered he had fixed its position, and I believe hoisted the British flag over the spot, taking possession thereof; but he may or may not have set up his dip circle over a position affected by serious magnetic disturbance, and therefore we must still be doubtful of his complete success from a magnetic point of view. Although eminent mathematicians have calculated its position, and Neumayer in 1885 gave a place to it on his charts of that year, we have still to wait for observation to settle the question, for one epoch at least.

Happily, I am able to repeat the good news that the Norwegian, Captain Roald Amundsen, sailed in June last with the express object of making a magnetic survey of Ross's position and of the surrounding regions, in order to fix the position of the north magnetic pole. Furnished with suitable instruments of the latest pattern, he proposes to continue his investigations until 1905, when we may look for his return and the fulfilment of our hopes.

So far as we can now see, the south magnetic pole cannot be approached very nearly by the traveller, and we can only lay siege to it by observing at stations some distance off but encircling it. We have our own expedition on one side of it, and now with the return of the *Gauss* to South Africa in June last, we have learnt that that vessel wintered in lat. 66° 2′ S., long. 89° 48′ E., a position on the opposite side of the supposed site of the magnetic pole to that of the *Discovery*. We may now pause to record our warm congratulations to Dr. von Drygalski and his companions on their safe return, accompanied by the welcome report that their expedition has proved successful.

In addition to the British and German expeditions, there are the Swedish expedition and the Scottish expedition. Therefore, with so many nationalities working in widely different localities surrounding it, we have every reason to expect that the position of the south magnetic pole will be determined.

The Secular Change.

When in the year 1600 Gilbert announced to the world that the earth is a great magnet, he believed it to be a stable magnet; and it was left to Gellibrand, some thirty-four years later, by his discovery of the annual change of the magnetic declination near London, to show that this could hardly be the case. Ever since then the remarkable and unceasing changes in the magnetism of the earth have been the subject of constant observation by magneticians and of investigation by some of the ablest philosophers in Europe and America. Year after year new data are amassed as to the changes going on in the distribution of the magnetism of the earth, but as yet we have been favoured by hypotheses only as to the causes of the wondrous changes which the magnetic needle records.

These hypotheses were at one time chiefly based upon a consideration of the secular change in the declination, but it is now certain that we must take into account the whole of the phenomena connected with the movements of the needle, if we are to arrive at any satisfactory result. Besides, it will not suffice to take our data solely from existing fixed observatories, however relatively well placed and equipped, and valuable as they certainly are, for it now appears that the secular change is partly dependent upon locality, and that even at places not many miles apart differences in results unaccounted for by distance have been obtained.

The tendency of observation is increasingly to show that the secular change of the magnetic elements is not a world-wide progress of the magnetic needle moving regularly in certain directions, as if solely caused by the regular rotation during a long series of years of the magnetic poles round the geographical poles, for if you examine Map No. 1, showing the results of observations during the years 1840–80 as regards secular change, you will observe that there are local causes at work in certain regions, whilst in others there is rest, which must largely modify the effect of any polar rotation.

Allow me to explain further. The plain lines on Map No. 1 indicate approximate regions of no secular change in the declination, and the small arrows the general direction (not the amount) in which the north-seeking end of the horizontal needle was moving during those forty years. The foci of greatest change in the declination, with the approximate amount of annual change in the northern hemisphere, are shown in the German Ocean and N.W. Alaska, in the southern hemisphere off the coast of Brazil, and in the South Pacific between New Zealand and Cape Horn. The two foci of greatest annual change in the dip are shown, one in the Gulf of Guinea where the north-seeking end of the needle was being repelled strongly upwards, the other on the west side of Tierra del Fuego, where the north-seeking end of the needle was being attracted strongly downwards.

It is remarkable that the lines of no change in the declination pass through the foci of greatest change in the dip. If the needle be repelled upwards, as at the Gulf of Guinea focus, it will be found to be moving to the eastward on the east side of the whole line of no change in the declination from the Cape of Good Hope to Labrador; to the westward on the west side. If the needle be attracted downwards, as at the Tierra del Fuego focus, it will be found moving to the westward on the east side of the whole line of no declination from that focus to near Vancouver Island; to the eastward on the west side.

A similar result may be seen in the line passing through a minor focus of the dip near Hong Kong.

Judging from analogy there should be another focus of change in the dip in lat. 70° N., long. 115° E., or about the position assigned to the Siberian focus of greatest force.

On Map No. 2 are shown lines of equal value of the declination—the red lines for the year 1880, the black lines for the year 1895. From these, when shown on a large scale, we may deduce the mean annual change which has taken place in the declination during the fifteen years elapsed.

In this map we are reminded of the different results we obtain in different localities, for if a line be drawn from Wellington in New Zealand past Cape York in Australia to Hong Kong, little or no change will be found in the neighbouring region since 1840. Again, the line of no change in the declination shown on Map No. 1 to be following much the same direction as the great mountain ranges on the west side of the American continent has hardly moved for many years according to the observations available.

On the other hand, let us now turn to an example of the remarkable changes which may take place in the declination unexpectedly and locally. The island of Zanzibar and the east coast of Africa were constantly being visited by our surveying-ships and ships of war up to the year 1880, observations of the declination being made every year at Zanzibar during the epoch 1870–80. The results showed that from Capetown nearly to Cape Guardafui the annual change of that element hardly exceeded 1′.

During the succeeding years of 1890–91 observations were made by the Germans at Dar-es-Salaam and some other places on the neighbouring coasts, with the result that the declination was found to be changing at first 3′ annually, and since that period it had reached 10′ to 12′ at Dar-es-Salaam. Subsequent observations at the latter place in 1896–98 confirmed the fact of the great change, and in addition our surveying-ship on the station, specially ordered to "swing" at different places in deep water off the coast, generally confirmed the results. It is remarkable that whilst such great changes should have taken place between Capetown and Cape Guardafui, Aden and the region about the straits of Bab-el-Mandeb seem to be comparatively unaffected.

Local Magnetic Disturbance.

In Map No. 2 normal lines of equal value of the declination are recorded, and so far as the greater part of the globe covered by water is concerned, we may accept them as undisturbed values, for we have yet to learn that there are any local magnetic disturbances of the needle in depths beyond 100 fathoms.

When, however, we come to the land, there is an increasing difficulty in finding districts of only a few miles in extent where the observed values of the magnetic elements at different stations therein do not differ more widely than they should if we considered only their relative position on the earth as a magnet. Take Rücker and Thorpe's maps of the British Isles and those of the United States, for example, where the lines of equal value are drawn in accordance with the observations, with the result that they form extraordinary loops and curves differing largely from the normal curves of calculation.

From among numerous examples of disturbance of the declination on land, two may be quoted. In the Rapakivi district, near Wiborg, a Russian surveying officer in the year 1890 observed a disturbance of 180°, or, in other words, the north point of his compass pointed due south. At Invercargill, in New Zealand, within a circle of 30 feet radius, a difference of 56° was found. Even on board ships in the same harbour different results are sometimes observed, as our training squadron found at Reikiavik in Iceland, and notably in our ships at Bermuda.

It is hardly necessary to add that the dip and force are often largely subject to like disturbance, but I do so in order to warn travellers and surveyors that observations in one position often convey but a partial truth; they should be supplemented by as many more as possible in the neighbourhood or district. Erroneous values of the secular change have also been published from the various observers not having occupied exactly the same spot, and even varied heights of the instrument from the ground may make a serious difference, as at Rapakivi before mentioned, and at Madeira, where the officers of the *Challenger* expedition found the dip at a foot above the ground to be 48° 46′ N.; at $3\frac{1}{4}$ feet above the ground 56° 18′ N. at the same spot.

All mountainous districts are specially open to suspicion of magnetic disturbance, and we know from comparison with normal observations at sea that those mountains standing out of the deep sea, which we call islands, are considerably so affected.

Magnetic Shoals.

The idea that the compasses of ships could be affected by the attraction of the neighbouring dry land, causing those ships to be unsuspectingly diverted from their correct course, was long a favourite theory of those who discussed the causes of shipwreck, but it was "a fond thing vainly invented." I can hardly say this idea is yet exploded, but from what has already been said about local magnetic disturbance on land, it is not a matter of surprise that similar sources of disturbance should exist in the land *under* the sea, for it has been found that in certain localities, in depths of water sufficient to float the largest ironclad, considerable disturbances are caused in the compasses of ships.

An area of remarkable disturbance having been reported as existing off Cossack, N.W. Australia, H.M.S. *Penguin*, a surveying-ship provided with the necessary magnetic instruments, was sent by the Admiralty in 1891 to make a complete magnetic survey of the locality, with a view to ascertain the facts and place them on a scientific basis. An area of disturbance 3·5 miles long by 2 miles broad, with not less than 8 fathoms of water over it, was found lying in a N.E. by E. and S.W. by W. direction. At one position the disturbing force was sufficient to deflect the *Penguin's* compass 56°; in another—the focus of principal disturbance—the dip on board was increased by 29°, and this at a distance of more than 2 miles from the nearest visible land, upon which only a small disturbance of the dip was found.

This remarkable area of disturbance was then called a "Magnetic Shoal," a term which at first sight hardly appears to be applicable. We have, however, become familiar with the terms "ridge line, valley line, peak, and col," as applied to areas of magnetic disturbance on land; therefore I think we may conveniently designate areas of magnetic disturbance in land under the sea "Magnetic Shoals."

This year H.M. surveying-ship *Research* has examined and placed a magnetic shoal in East Loch Roag (Island of Lewis), but as all our surveying-ships are practically iron ships, it was impossible from observations on board to obtain the exact values of the disturbing forces prevailing in this shoal. The reason for this is that, although we may accurately measure the disturbing forces of the iron of the ship in deep water, directly she is placed over the shoal induction takes place, and we can no longer determine to what extent the observed disturbances are due to the ship's newly developed magnetism, or to what extent the shoal alone produces them.

We can, nevertheless, even in an iron ship, accurately *place* and show the dimensions of a magnetic shoal and the *direction* in which a ship's compass will be deflected in any part of it by compass observations only. Is it not, therefore, the duty of any ship meeting with such shoals to stop and fix their position?

The general law governing the distribution of magnetism on these magnetic shoals is that in the northern hemisphere the north point of the compass is drawn *towards* the focus of greatest dip; in the southern hemisphere it is *repelled*. The results at East Loch Roag proved an exception, the north point of the compass being *repelled*.

Terrestrial Magnetism and Geology.

I have already referred to the question of local magnetic disturbance as one of great importance in magnetic surveys. The causes of these disturbances were at one time a matter of opinion, but the evidence of the elaborate magnetic surveys I have alluded to, when compared with the geological maps of the same countries, points clearly to magnetic rocks as their chief origin.

Magnetic rocks may be present, but from their peculiar position fail to disturb the needle; but, on the other hand, as Rücker writes in his summary of the results of the great magnetic survey of the British Isles conducted by Thorpe and himself, "the magnet would be capable of detecting large masses of magnetic rock at a depth of several miles," a distance not yet attained by the science of the geologist.

Again, Dr. Rijckevorsel, in his survey of Holland for the epoch 1891, was convinced that "in some cases, in many perhaps, there must be a direct relation between geology and terrestrial magnetism, and that many of the magnetic features must be in some way determined by the geological structure of the under-ground."

During the years 1897–99 a magnetic survey was made of the Kaiser-stuhl, a mountainous district in the neighbourhood of Freiburg, in Baden, by Dr. G. Meyer. Exact topographical and geological surveys had been previously made, and the object of the magnetic survey was to show how far the magnetic disturbances of the needle were connected with geological conformations. Here, again, it was found that the magnetic and geological features of the district showed considerable agreement, basaltic rocks being the origin of the disturbance. This was not all, for in the level country adjacent to the Rhine and near Breisach unsuspected masses of basalt were found by the agency of the magnetic needle.

More recently we find our naval officers in H.M.S. *Penguin*, with a complete outfit of magnetic instruments, making a magnetic survey of Funafuti atoll and assisting the geologist by pointing out, by means of the observed disturbance of the needle, the probable positions in the lagoon in which rock would be most accessible to their boring apparatus.

Leaving the geologist and the magnetician to work in harmony for their common weal, let us turn to some other aspects of the good work already accomplished and to be accomplished by magnetic observers.

Magnetic Charts.

Of the valuable work of the several fixed magnetic observatories of the world, I may remark that they are constantly recording the never-ceasing movements of the needle, the key to many mysteries to science existing in the world and external to it, but of which we have not yet learnt the use. Unfortunately many of these once fixed observatories have become travellers to positions where the earth can carry on its work on the needle undisturbed by electric trams and railways which have sprung up near them, and it is to be hoped they will find rest there for many years to come.

Of the forty-two observatories which publish the values of the magnetic elements obtained there, thirty-two are situated northward of the parallel of 30° N., and only four in south latitude; and it is a grief to magneticians that so important a position as Capetown or its neighbourhood does not make an additional fixed magnetic observatory of the first order.

Thus, so far as our present question of magnetic charts and their compilation is concerned, the observatories do not contribute largely, but we should be very grateful to them for the accurate observations of the secular change they provide which are so difficult to obtain elsewhere.

Of the value of magnetic charts for different epochs I have much to say, as they are required for purely scientific inquiry as well as for practical uses. It is only by their means that we can really compare the enormous changes which take place in the magnetism of the globe as a whole; they are useful to the miner, but considerably more so to the seaman.

Had it not been for the charts compiled from the results of the untiring labours of travellers by land and observers at sea in the field of terrestrial magnetism during the last century, not only would science have been miserably poorer, but it is not too much to say that the modern iron or steel steamship traversing the ocean on the darkest night at great speed would have been almost an impossibility, whereas with their aid the modern navigators can drive their ships at a speed of 26·5 statute miles an hour with comparative confidence, even when neither sun, moon, nor stars are appearing.

Of the large number of travellers by sea, including those who embark with the purpose of increasing our geographical knowledge of distant lands and busying themselves with most useful inquiries into the geology, botany, zoology, and meteorology of the regions they visit, few realise that when they set foot on board ship (for all ships are now constructed of iron or steel) they are living inside a magnet. Truly a magnet, having become one by the inductive action of that great parent magnet—the Earth.

How fares the compass on board those magnets, the ships, that instrument so indispensable to navigation, which Victor Hugo has forcibly called "the soul of the ship," and of which it has been written,

"A rusted nail, placed near the faithful compass,
Will sway it from the truth, and wreck an argosy"?

And if so small a thing as an iron nail be a danger, what are we to say to the iron ship? Let us for a moment consider this important matter.

If the nature of the whole of the iron or steel used in construction of ships were such as to become permanently magnetic, their navigation would be much simplified, as our knowledge of terrestrial magnetism would enable us to provide correctors for any disturbing effects of such iron on the compass, which would then point correctly. But ships, taken as a whole, are generally more or less unstable magnets, and constantly subject to change, not only on change of geographical position, but also of direction of the ship's head with regard to the magnetic meridian. Thus a ship steering on an easterly course may be temporarily magnetised to a certain extent, but on reversing the ship's course to west she would after a time become temporarily magnetised to the same amount, but in the opposite direction, the north point of the compass being attracted in each case to that side of the ship which is southernmost.

Shortly, we may define the action of the earth's magnetism on the iron of a ship as follows: The earth being surrounded by a magnetic field of force differing greatly in intensity and direction in the regions from the North Pole to the Equator and the Equator to the South Pole, the ship's magnetic condition is largely dependent upon the direction of her head whilst building and the part of that field she occupied at the time; partly upon her position in the magnetic field she traverses at any given time during a voyage.

For the reasons I have given, magnetic charts are a necessity for practical purposes and in the following order of value. That of the magnetic declination or variation which is constantly in use, especially in such parts of the world as the St. Lawrence and the approaches to the English Channel, where the declination changes very rapidly as the ship proceeds on her course. Next, that of the dip and force, which are not only immediately useful when correcting the ship's compass, but are required in the analysis of a ship's magnetism both as regards present knowledge and future improvements in placing compasses on board.

If astronomers have for a very long time been able to publish for several years in advance exact data concerning the heavenly bodies, is it too much to hope that magneticians will before long also be able to publish correct magnetic charts to cover several years in advance of any present epoch? If this is to be done within reasonable time there must be a long pull, a strong pull, and a pull all together of magnetic observers in all lands, and accumulated data must also be discussed.

On Magnetic Instruments for Travellers.

Travellers in unsurveyed countries, if properly instructed and equipped, can do good service to science by observing the three magnetic elements of declination, inclination or dip, and force at as many stations as circumstances will permit; hence the following remarks.

For the purpose of making the most exact magnetic survey the best equipment of instruments consists of the well-known unifilar magnetometer, with fittings for observing the declination, and a Barrow's dip circle. To some travellers these instruments might be found too bulky, and in some regions too delicate as well as heavy to carry.

Of suitable instruments made abroad, those used by M. Moureaux in his survey of France may be mentioned, as they are of similar type, but much smaller and lighter than the instruments above mentioned.

Another form of instrument, called an L.C. instrument, for observing both the inclination and total force, is shown in the instrument before you. Originally designed for observations on board ships at sea where the ordinary magnetic instruments are unmanageable, it has also been found to give satisfactory results in a land survey, where greater accuracy is expected than at sea. Thus, during a series of observations extending from the north side of Lake Superior to the southern part of Texas last year, comparisons were made between the results obtained with an L.C. instrument and those of the regular unifilar magnetometer and dip circle, when the agreement was found satisfactory.

I am therefore of the opinion that a traveller furnished with a theodolite for land-surveying purposes, but fitted with a reversible magnetic needle, can at any time he observes a true bearing obtain a trustworthy value of the declination. Dismounting the theodolite from his tripod, the latter will serve for mounting an L.C. instrument with which to observe the inclination and force. Thus, by adding to his ordinary equipment an instrument weighing in its box about 21 lb., he can obtain valuable contributions to terrestrial magnetism, and at the same time give useful assistance to geological investigations.

Concluding Remarks.

Although a great subject like terrestrial magnetism, even to exhibit our present knowledge of the science, cannot be brought within the compass of an address—for it requires a treatise of many pages—I have brought some of the broad features of it before the Section in order to show its connection with Geography.

I also entertain the hope that geographers will become more interested in a subject so important to pure science and in its practical applications, and that it will become an additional subject to the instruction which travellers can now obtain under the auspices of the Royal Geographical Society in geology, botany, zoology, meteorology, and surveying.

There is a wide field open to observers, and where results often depend so much upon locality we require to explore more and more with the magnetic needle. To look over the great oceans and think how little is being done for terrestrial magnetism is a great matter for regret. Yet even there we may begin to be hopeful, for the United States Coast and Geodetic Survey authorities are making arrangements to fit out its vessels with the necessary instruments for determining the magnetic elements at sea.

We wish them all success; but I must again remind you that although we cannot compel observers to start, there is room for them and to spare.

I would fain make some remarks on the prevailing ignorance of sound geography in many quarters, and on the defective methods of teaching the science; but I feel that the subject is placed in very able hands, and will be fully discussed elsewhere during the present meeting.

SECTION G.

ENGINEERING.

OPENING ADDRESS BY MR. CHARLES HAWKSLEY, PAST PRESIDENT INST.C.E., PRESIDENT OF THE SECTION.

SINCE the last meeting of the British Association there has passed from our midst, to the deep regret of all who had the privilege of knowing him, one who, though full of years, actively followed his profession as a Civil Engineer until within a few days of his death. I refer to Mr. Edward Woods, who presided over Section G of the British Association at Plymouth in 1877. Mr. Woods commenced his professional career on the Liverpool and Manchester Railway soon after it was opened for traffic. In 1875 Mr. Woods was invited by the Royal Commission on Railway Accidents to undertake, in conjunction with Colonel Inglis,

R.E., an exhaustive series of trials of the different kinds of railway brakes then in use in England, the results of which were recorded in an elaborate and valuable report. These trials were referred to by Mr. Woods in his address as President of Section G. Mr. Woods was President of the Institution of Civil Engineers in 1886–1887, and he died on June 14, 1903, at the ripe age of eighty-nine.

TECHNICAL EDUCATION.

The subject of the technical education of engineers was treated very fully in the interesting address delivered by Prof. Perry, as President of Section G at the meeting of the British Association in Belfast last year. This question also received thorough consideration at the meeting of the Engineering Conference held in London in June last, as well as at recent meetings of the Institution of Mechanical Engineers and of the Institute of Naval Architects. The systems in vogue in the United States of America and on the Continent of Europe were on those occasions brought forward in carefully prepared papers and fully discussed. The main points at issue are: (1) whether actual handicraft should be taught in the Technological School or College along with the principles underlying the Engineers' art; (2) whether the year should be divided into periods in one or more of which the science of engineering should be taught, and in another or others of which craft skill should be acquired at works; (3) whether the principles should be first acquired, during a longer or shorter term, leaving experience in applying those principles to be gained at the termination of the course. As regards the first of these suggestions it appears to be in opposition to the judgment of the most experienced teachers. In respect to the second, the Admiralty have carried it out for the last forty years, and with satisfaction to the Service; it is also common in Glasgow, and Mr. Yarrow has included this system in the apprenticeship rules he has recently laid down, whilst it is to be tried experimentally in the Engineering Course at King's College, London. At the Engineering Conference it was determined that the subject was of such importance that its further consideration should be left to a Committee, to be subsequently appointed.

Since the British Association last met in Lancashire (in 1896) there have been important events and changes in the chief technical institutions of the county. First, there were last year the Jubilee celebrations of Owens College, Manchester, when it received congratulations on its half-century of work from universities and learned societies in all parts of the world. Here, as I need hardly remind you, the engineering laboratory is under the able direction of Prof. Osborne Reynolds, F.R.S., who presided over Section G of the British Association at their Meeting in Manchester in 1887. Then, also in Manchester, there is the recently completed and admirable Municipal School of Technology; but as a paper will be read on this subject, and members will have an opportunity of visiting the school and inspecting its engineering laboratory, I will content myself with wishing it every success in the manifold fields of industrial education in which it is engaged. Again, only this year Victoria University has lost a College, and Liverpool has gained a University. At University College, Liverpool, in the Session of 1884–5, a Professorship of Engineering was instituted as a provisional measure. The erection of engineering laboratories and the endowment of the Chair were afterwards provided for by gifts in commemoration of the Jubilee year of the reign of Her late Majesty, Queen Victoria. Prof. H. E. Hele-Shaw, F.R.S., was appointed to the Chair in the first instance, a position which he still continues to hold.

This year a Royal Charter has been granted establishing the University of Liverpool, and transferring to it the powers of University College, Liverpool. I think one cannot offer to the University of Liverpool a heartier wish than that it may be as successful in the future as University College, Liverpool, has been in the past, a wish in which I am sure you will all join.

There is yet one other college to which, though not in Lancashire, I should like to make a passing reference, the first to include engineering in its educational curriculum, viz. University College, London. It was originally founded in 1828 under the name of the "University of London," and has recently, together with King's College, become merged in the present University of London. The first engineering laboratory was established at University College in 1878, fifty years after the inauguration of the college, whilst a separate chair for electrical engineering was founded in 1885, and an electrical laboratory was added ten years ago. One cannot say farewell to it as it used to be without mentioning the name of Dr. A. B. W. Kennedy, F.R.S., who was President of this Section of the British Association in 1894 at Oxford, and who has done so much for engineering education.

Before leaving the subject of technical education, I venture to express the hope that in the training of engineering students increased attention will be paid to the combination of artistic merit with excellence of structural design, so that in respect to artistic treatment our engineering structures may not remain so far behind those of our Continental brethren as is unfortunately now frequently the case.

ENGINEERING STANDARDS.

A very important work has been going on quietly and unostentatiously in our midst for some time past, the results of which must affect the engineering profession at home and abroad. I refer to the work of the Engineering Standards Committee, which as many of my hearers know, was appointed in 1901 and is now composed of 178 members, among whom are many Government officials. I alluded to the earlier work of this Committee in my Presidential Address to the Institution of Civil Engineers in 1901, and that work has since been gradually but surely extended. The Committee has received not only the moral but the financial support of His Majesty's Government, and the results of its labours are being adopted by all the leading Government departments.

In addition to the main Committee there are no fewer than twenty-five separate committees and sub-committees engaged on work, covering a wide range of operations, many of the members sitting on more than one committee.

A few details of the work accomplished and in progress may be of interest. After careful deliberation the Committee published their first series of British standards sections, covering all rolled steel sections used in constructional work, shipbuilding and so forth. The Committee on Rails has just issued the standard sections and specification for British girder tramway rails, and it is now actively engaged in drawing up a series of standard sections of bull-headed and flat-bottomed rails for railway work.

Another committee of a thoroughly representative character is occupied in drawing up a standard specification and standard tests for cement, and a standard specification drawn up by so large a body of our leading engineers, contractors, and manufacturers must be of great interest to all those who are called on to specify tests for this material.

The Government of India control to a very considerable extent the working of railways in India, and they have referred to the Standards Committee the important question of drawing up a series of standard types of locomotives for use on the Indian railways. The Committee which investigated this difficult subject has just forwarded its report to the Secretary of State for India. Other committees are preparing standard specifications for locomotive copper firebox plates and steel boiler plates, which it is hoped will be published at an early date.

The subject of screw-threads is one which has occupied a Committee of the British Association for some years past, and I am glad to learn that the Committee of this Association has been co-operating with the Standards Committee and discussing the question of screw-threads of both smaller and larger diameters, and also considering the cognate subject of limit gauges so essential to all accurate work in mechanical engineering.

Another Committee is dealing with standard flanges, and I understand it is shortly proposed to consider the standardisation of cast-iron pipes.

A very large and influential committee is engaged on the subject of the materials used in the construction of ships and their machinery, and most valuable information is being collected with a view to the preparation of a standard specification for steel and to the determination of forms for standard test-pieces to be used when testing plates, forgings, castings, and so forth.

There are about half a dozen committees engaged on various important electrical subjects, but as their work will

no doubt be referred to in another Section of this Association, I do not propose to make further reference to it here.

In my Presidential Address before the Institution of Civil Engineers in 1901, I raised a note of warning in regard to the stereotyping of design and the consequent cramping of originality. The constitution of the Standards Committee and the professional standing of its members afford a guarantee that its work will accord with the best practice of this country, since those engaged in drawing up the standards are not only in the forefront of engineering practice, but are alive to the necessity for extending the number of standards if and when needed to meet the requirements of the engineer.

NATIONAL PHYSICAL LABORATORY.

An outline scheme for a National Physical Laboratory was set forth in 1891, by Sir (then Dr.) Oliver Lodge, F.R.S., in his Address at Cardiff to Section A of the British Association. In his Presidential Address to this Association in 1895 at Ipswich, the late Sir Douglas Galton, F.R.S., emphasised the importance of such an Institution, a Committee of this Association reported in favour of it, and later, when after forwarding a petition to the late Lord Salisbury, a Treasury Committee with Lord Rayleigh, F.R.S., in the Chair was formed, Sir Douglas Galton gave evidence to the effect that if Great Britain was to retain its industrial supremacy, we must have accurate standards available to our research students and to our manufacturers.

In 1901, the National Physical Laboratory was inaugurated at Bushy House, near Teddington, and an annual grant of 4000*l.* towards its support was made by Government. It is divided into three departments, of which the one dealing with all branches of Civil, Mechanical, and Electrical Engineering is chiefly interesting to us in Section G In this department tests are now undertaken of the strength of materials of construction, of pressure and vacuum gauges, of indicators and indicator springs, and of length gauges and screw gauges, and photomicroscopic investigation is made of metals and alloys, and especially of steel rails.

But beside the ordinary work of testing, various investigations are in progress, such as measurement of wind pressure, elastic fatigue in nickel steel and other materials used by engineers, and the magnetic and mechanical properties of aluminium-iron and other alloys. For the British Association a set of platinum thermometers has been constructed and subjected to stringent tests, and an investigation has been undertaken for the Engineering Standards Committee into the changes in insulating strength of various dielectrics used in motors, transformers, &c., due to continued heating. In the language of Dr. Glazebrook, F.R.S., the Director, who it may be mentioned was previously Principal of University College, Liverpool, science is not yet regarded as a commercial factor in this country, but it is one of the aims of the National Physical Laboratory to bring about the alliance of science with commerce and industry. The expenditure of the National Physical Laboratory is met by an annual Treasury grant of 4000*l.*; 500*l.* a year from an endowment; fees for tests, now amounting to about 3500*l.* annually; and from donations and subscriptions.

The Director is anxious that the revenue derived from fees for testing should be largely augmented, and I would urge on engineers, contractors and manufacturers, as well as on private individuals, that they should avail themselves of the opportunity to have tests and experiments of interest to them, and which will be generally accepted as unimpeachable, conducted at this laboratory. I may add that an appeal has been made for further donations and annual contributions, as the funds now at the disposal of the Board of Management are insufficient to carry on the work of the laboratory on a sound financial basis, and I venture to hope that many of those who are interested in the practical applications of science will assist in supporting the work of this national institution.

INTERCOMMUNICATION.

General Progress.

At the commencement of the nineteenth century, Southport, which now has its parks, a promenade, and a pier more than three-quarters of a mile in length, its halls, free library, art gallery and science and art schools, and railway connection with all parts of the kingdom, was not even to be found on the maps, the first house having been erected in the year 1792. In 1851 the population of Southport and the adjoining place Birkdale was 5390, whereas at the census of 1901, Southport had a population of 48,083 and Birkdale 14,197, together 62,280. Here is evidence of great local enterprise, resulting in a development of which its people may be justly proud.

At the commencement of the nineteenth century the population of the United Kingdom was nearly $15\frac{3}{4}$ millions, at the beginning of the twentieth nearly $41\frac{1}{2}$ millions. Then there was not a mile of railway in the United Kingdom: now there are about 22,000 miles. Here, too, is evidence not only of the prosperity which has prevailed throughout Great Britain during the century that has passed, but also of the enormously increased demands which have arisen during the same period on the means of locomotion.

It was towards the latter half of the eighteenth century that the formation of good roads was commenced in Lancashire and the adjoining counties by John Metcalf, the blind road-maker, and that Palmer in 1784 introduced mail coaches travelling at from six to seven miles an hour on the main roads. In 1801 the mail coach from London to Holyhead occupied nearly forty-six hours on the journey, and the mails reached Dublin on the third day after leaving London. Now the journey from London to Holyhead is performed in $5\frac{3}{4}$ hours, and Dublin is reached in $9\frac{1}{4}$ hours after leaving London.

In 1803, just one hundred years ago, Telford reported to the Government on the state of the roads, and as a result the great road to Liverpool from the Metropolis and the other great highways were constructed. It was enlightened wisdom that eighty years ago placed intercommunication in the forefront of the definition of engineering; it still maintains that position, and I purpose to say a few words on the present aspect of the question.

Road Traffic—Motors.

Speed in locomotion appears to be now the first consideration, whether as regards mails, passengers, or goods. I would refer in the first instance to locomotion on our main roads. Here three or four classes of machines appear to be ambitious to drive pedestrians, horsemen, and horse-drawn vehicles off the road.

The first practical steam carriage was used by Trevithick in the year 1802; and now, a hundred years later, it is found that for the traction of heavy loads on the main roads steam is still most suitable. The points of importance in connection with traction engines and their trailers are their speed, weight, and width; of course, there is no question that, as regards facilitating traffic, the large heavy waggon replacing many smaller horse-drawn ones will be found a boon. Mr. E. R. Calthrop, M.Inst.C.E., one of the founders of the Liverpool Self-propelled Traffic Association, is opposed to any weight restriction, but it must be remembered that the momentum of heavily laden waggons drawn by a powerful traction engine at the maximum speed of five miles an hour is very great, and causes uncomfortable vibration in the houses along the main thoroughfares of our towns; on the other hand, light traction engines are now being successfully used, drawing from four to five tons of market produce through the streets of London without causing undue vibration, and at a cost, I am informed, of about one-half that of horse traction.

But a far more burning question is that of the speed of motor cars along our public thoroughfares. The struggle to maintain a trophy at home, or to regain it from abroad, is one in which every inhabitant of this country sympathises. The great Gordon-Bennett Cup Race in July last redounded to the credit of the Automobile Club of Great Britain and Ireland, who made and carried out the arrangements and were at considerable pains to find a suitable course in a sparsely inhabited district; every measure which experience has shown to be needful having been taken to prevent accident. The race was decidedly international in character, French, Germans, Americans, and English contesting for the prize; and in heartily congratulating the German Automobile Club on their success, it may be noted that M.

Jenatzy covered a distance of $327\frac{1}{2}$ miles in 6 hours 39 minutes, or at the rate of $49\frac{1}{4}$ miles an hour, though he attained to a speed of 61 miles an hour between the points of control. Even this speed was exceeded at a trial in Phœnix Park, Dublin, when Baron de Forest attained to a rate of 86 miles an hour. But between racing speed and ordinary travelling speed there is necessarily a great difference, and our twenty miles maximum on country roads is in excess of that allowed in France, where it is now fixed, though I believe not enforced in the open country, at $18\frac{1}{2}$ miles, and at $12\frac{1}{2}$ miles where there is much traffic. The two classes of motors used for higher speeds are the petrol and the electric. The former are mainly internal-combustion engines; having to be light, they run at the comparatively high speed of 800 revolutions per minute. They are generally used in connection with bicycles, tricycles, or light carriages. They have also been used for light vans and coaches, and successful trials have been made with self-propelled lorries for military purposes, and by local authorities for watering and dust collecting. Their application to omnibuses has not proved economical, owing to the difficulty of providing pneumatic tyres for such heavy vehicles.

The electric motor depends on storage batteries; those in general use are of Planté's lead-couple type. Like the petrol motor, the electric motor is rather a luxury; most of the automobile carriages used in London are of this class; there is liability of injury to the batteries by over-discharging them. Colonel Crompton, in a paper recently read at the Engineering Conference, suggested the use of "standardised accumulators," to be supplied to the owners of electrical vehicles at depôts on production of a subscription ticket, and the Engineering Standards Committee has appointed a sub-committee to consider the question. Motor cars are now used by some of the railway companies as feeders to their lines, and also in competition with tramway lines.

The increasing use of motor cars renders more than ever necessary the regulation of traffic in crowded thoroughfares, a subject which will doubtless be dealt with in the paper on "The Problem of Modern Street Traffic," which Colonel Crompton is about to read before this Section of the British Association.

The use of motor-driven vehicles for road traffic is so intimately associated with improvements in prime movers that it will interest the members of this Section to be reminded of the opinion expressed more than twenty years ago by Sir Frederick Bramwell, F.R.S., Past President Inst.C.E., who presided over the Meeting of the British Association at Bath in 1888. In a paper read before this Section at the Jubilee Meeting of our Association at York in 1881, and afterwards printed *in extenso*, Sir Frederick Bramwell said: "However much the Mechanical Section of the British Association may to-day contemplate with regret even the mere distant prospect of the steam-engine becoming a thing of the past, I very much doubt whether those who meet here fifty years hence will then speak of that motor except in the character of a curiosity to be found in a museum." In a letter addressed to the President of this Association on July 2 last, Sir Frederick Bramwell directed attention to the largely increasing development of internal-combustion engines, and expressed a feeling of assurance that, although steam-engines might be at work in 1931, the output in that year would be small of steam as compared with internal-combustion engines.

To keep alive the interest of the Association in this subject, Sir Frederick Bramwell has kindly offered, and the Council has accepted, the sum of 50*l*. for investment in $2\frac{1}{2}$ per cent. self-accumulative Consols, the resulting sum to be paid as an honorarium to a gentleman to be selected by the Council to prepare a paper having Sir Frederick's utterances in 1881 as a sort of text, and dealing with the whole question of the prime movers of 1931, and especially with the then relation between steam-engines and internal-combustion engines. That paper will doubtless prove to be a very valuable contribution to the proceedings of this Association, and one can only regret that many of those assembled here to-day cannot hope to be present when it is read, and to listen to an account of the nearest approach which has then been made towards the production of a perfect prime mover.

Electric Tramways and Light Railways.

I now pass to the application of electricity to tramways, and in doing so may quote from the careful expression of opinion given in this town from this Chair twenty years ago by the late Sir (then Mr.) James Brunlees, President of the Institution of Civil Engineers: "The working of railways by electricity has not advanced further than to justify merely a brief reference to it in this paper as among the possibilities, perhaps the probabilities, of the not distant future."

It was stated in a paper read by Mr. P. Dawson in April last before the Tramways and Light Railways Association, that the total route-length of electric tramways and light railways in the United Kingdom, either completed, under construction, or authorised, amounted at the end of last year to 3000 miles, the length of single track being 5000 miles, on which some 6000 cars were running.

It cannot, in my opinion, be regarded as being fair to the railway companies—which have to pay large sums of money for the land on which their lines have been constructed—to have to compete with tramways which are laid along the public roads without any payment being made for their use. The roads are disfigured by aërial conductors and the supporting posts by which the electric current is conveyed to the cars, except in those comparatively rare instances in which the conduit system is used; nor can it be denied that tramways greatly interfere with the use of the roads for ordinary traffic. The effect of electrolytic action on iron pipes laid beneath the roads is still undergoing investigation.

Railways.

Turning now to railways, it may be noted that on some of the principal lines in Great Britain the length of the runs without a stop is being increased in the case of fast trains, the speed of which is in some cases from forty-eight to fifty-nine miles an hour.

Railway companies are turning their attention to the introduction of electric traction wherever it can be beneficially used, as for instance on the Mersey Railway, the North-Eastern Railway between Newcastle-upon-Tyne and Tynemouth, and the Lancashire and Yorkshire Railway between Liverpool and Southport. With the object of facilitating the introduction and use of electrical power on railways, Parliament has passed an Act entitled the "Railways (Electrical Power) Act, 1903," which will come into operation on January 1 next.

The electrical service on the Mersey Railway has now been in regular and uninterrupted operation since the beginning of May in the present year. Trains are run at three-minute intervals, there being 750 trains in all between 5 a.m. and 12 midnight; and as it is the first example of a British steam railway converted to the use of electric traction, a short description of it cannot fail to be of interest.

The Mersey Railway was first opened for traffic on February 1, 1886, and was afterwards extended at both ends, the last extension to the Liverpool Central Station being opened for traffic in January, 1892. With steam locomotives, largely owing to the want of adequate ventilation, the railway was not a success. Electrification was decided upon, and in the latter part of 1901 the British Westinghouse Electric and Manufacturing Company, Limited, undertook the entire contract. The length of the railway is about $3\frac{3}{4}$ miles, and there are gradients in the tunnel below the river of 1 in 27 and 1 in 30.

The power station is at Birkenhead, and contains plant aggregating more than 6000 horse-power, comprising three engines of the Westinghouse-Corliss vertical cross-compound type.

The generators are all three alike, mounted on the engine shaft between the cylinders. They are standard Westinghouse multipolar machines, of the double-current type, of 1250 kilowatts capacity. Direct-current is collected from the armature at 650 volts, no alternating current being used at present.

Leads are carried below the floor from the machines to a switchboard, from which are controlled the main generators, the auxiliary lighting sets, battery, booster, and feeders. The battery consists of 320 chloride cells connected in parallel with the generators through a differential booster, and charge or discharge according as the line

load is light or heavy. They have a capacity of 1000 ampere-hours, and a momentary discharge capacity of 2000 amperes.

The auxiliary sets, two in number, are for lighting purposes, and yielding direct current at 650 volts, are available in case of need to supply current to the main traction circuits. 210 volt incandescent lamps are used for lighting, arranged in groups of three in series.

The feeders are carried from the switchboard down the ventilation shaft to feed the insulated electrical collector rails, which are placed in the space between the up and the down lines, and somewhat above the level of the rails, an insulated return collector rail being placed between each pair of rails. A train consists of two motor cars, one at each end, and from one to three trailers as required, depending on the amount of traffic. The motor cars each carry an equipment of four Westinghouse motors of 100 horse-power, making 400 horse-power per car, or 800 horse-power per train. These motors are all controlled in unison from the motorman's compartment at either end of the train by means of the Westinghouse multiple controlled system, which has worked from the start without a hitch.

In conclusion, it may be noted that every precaution has been taken against fire. The electrical equipment is all thoroughly fireproof, and the motorman's compartment is encased in asbestos slate, cutting it off completely from the remainder of the train.

Of tube railways with electric traction there are three now working in London, two between the City and the south side of the River Thames, using the ordinary two wire 500 volts continuous current system, and another (the Central London) extending from the City to Shepherd's Bush, using the composite system. This railway conveyed during the year 1902 no fewer than 45 million passengers. There are eight other tube railways now in course of construction in London. The recent terrible catastrophe in Paris must serve as a warning in the future equipment of such lines where currents at high tension are employed, and where short-circuiting may bring about disastrous results.

A paper will be read before this Section by Mr. F. B. Behr on the authorised Manchester and Liverpool Express Railway, which is intended to be constructed on the Monorail system, and to be worked electrically.

Canals.

Concurrently with the construction of roads in this country was the formation of canals, as a means of inland communication, mainly for the carriage of minerals and merchandise, though they also conveyed passengers by express boats. The only recent structure of this character in the United Kingdom is the famous Manchester Ship Canal, with which the name of Sir E. Leader Williams, M.Inst.C.E., is associated. This, however, is hardly a canal in the sense in which that word was employed by Brindley, "the father of inland canal navigation in England," as the largest amount by far, in the proportion of 10 to 1, is its seaborne as compared with its local traffic. It is interesting to notice that a very important wheat trade is being carried on with India, exported both from Bombay and Kurrachee. The seaborne traffic and the barge traffic for 1894 was 686,158 tons and 239,501 tons respectively, and has during eight years increased, until in 1902 it had reached 3,137,348 tons and 280,711 tons respectively. The most interesting recent development of the works is the new Dock now in course of construction, with its five sets of transit sheds, which are being built on the Ferro-Concrete system.

Ships.

The intercommunication of the nations of the world is largely dependent on the navigation of the ocean. The first vessel to cross the Atlantic fitted with steam power was the *Savannah,* of about 300 tons, which arrived at Liverpool from Savannah, in Georgia, in thirty days, partly under steam and partly under sail. Ocean steam traffic has been extending ever since. Two years ago I had occasion, in connection with my Presidential Address to the Institution of Civil Engineers, to collect some statistics with regard to shipping, and found that according to Lloyd's Register the largest British vessels then afloat were the twin-screw steamers *Oceanic*, of 17,274 tons, and the *Celtic*, of 20,904 tons, both gross register, built for the White Star line, and regularly making the passage between Liverpool and New York in seven days and eight days respectively; and the *Celtic* is still the largest mercantile steamship afloat, the tonnage of the new German steamer, *Kaiser Wilhelm II.*, being 19,360 tons gross register.

Unfortunately these fine ships, with many others, are now no longer owned in this country, although still flying the British flag. The latest German steamer on the American line, together with others recently launched from the Vulcan Works at Stettin, have maintained a speed averaging more than 23 knots, whilst the Cunard Company's liners—still, happily, English—the *Campania* and *Lucania*, built ten years ago, average 22 knots. This company is under contract with the Government to build two liners to maintain an average speed of 24½ knots. The secretary of "Lloyd's Register of British and Foreign Shipping" has kindly supplied me with a list of the steamers of 10,000 tons and upwards which have been launched in the United Kingdom between 1900 and June, 1903. It is given in aggregate below :—

Year	No. of ships	Aggregate gross tonnage
1900	8	95,275
1901	8	107,396
1902	7	98,505
1903 (six months to June 30)	6	67,600 (approximate)

In the Address already referred to I mentioned the application as having been then recently made of the Parsons steam turbine to H.M. torpedo-boat destroyers. The South-Eastern and Chatham Railway Company's new steamer *The Queen* has been fitted with this class of engine of latest design. There is a central high-pressure turbine, driving its shaft at 700 revolutions a minute, and two side low-pressure turbines, each driving its separate shaft at 500 revolutions a minute. The steamer is 310 feet long, and is now running successfully in the service between Dover and Calais.

For some time past much attention has been paid, more especially in France, to the perfecting of submarine vessels for the purposes of naval warfare, but it cannot yet be said that they have passed beyond the experimental stage, although the advance made has been such as to cause our Admiralty to order several additional vessels of the submarine type. These vessels are to be propelled by internal-combustion engines when on the surface of the water and by electric motors when submerged.

Aëronautics.

Another of the attempted means of locomotion is that of aërial navigation. How little we appear to have advanced beyond where we were fifty years ago, when on September 24, 1852, that eminent French engineer, Henri Giffard, succeeded during an experimental ascent in Paris in driving a balloon against the wind for a very short distance, although on October 19, 1901, M. Santos Dumont was successful in navigating his balloon from St. Cloud round the Eiffel Tower in Paris and back to the spot where he had started only half an hour previously. Many have been engaged in this so far unsolved problem of aërial navigation, but there is one of whom we seldom hear. I will quote what Dr. Janssen said in his Presidential Address to the International Aëronautic Congress, held in France on September 15, 1900, regarding Mr. Langley, Correspondent of the Institute of France and Secretary of the Smithsonian Institution at Washington. "Independently of the fine and profound researches of this investigator upon the resistance of air, Mr. Langley has constructed an aëroplane which has progressed and has sustained itself during a time notably longer than any of the apparatus previously constructed."

In the last report of the Smithsonian Institution, that for 1901, it is stated that this steel flying-machine had a supporting area of 54 square feet, a weight of 30 lb., developed 1½ horse-power, and repeatedly flew from one-half a mile to three-quarters of a mile. I cannot close this portion of my Address without referring to the death on February 7

last, in the ninety-fourth year of his age, of that eminent scientific aëronaut, Mr. James Glaisher, F.R.S., who in 1863 made his famous ascent to an altitude of seven miles, and who described at the Newcastle-upon-Tyne Meeting in that year, in an evening lecture, the balloon ascents made for the British Association.

Wireless Telegraphy.

In addressing this Section I feel that I ought to say a few words on the subject of "wireless telegraphy." With regard to signalling Signor Marconi certainly seems to have made progress. In January, 1901, signals were conveyed from Poldhu in Cornwall to the Isle of Wight, a distance of 200 miles, and in December of the same year, between Cornwall and St. John's, Newfoundland, a distance of 2000 miles. In the year 1902 signals were transmitted from England to the Baltic and the Mediterranean, which had thus passed over both sea and land. It seems to be not improbable that signals can be sent any distance, so long as the sending station can develop sufficient energy. The question of "syntonism," by which it is proposed to assure the secrecy of messages, appears to be still *sub judice*, but is undergoing further investigation.

There appears to be a practical field for the development of "wireless telegraphy," more especially where ordinary telegraphy cannot be applied, as, for instance, between shore and ships at sea or between one ship and another.

The Marconi Wireless Telegraph Company have obligingly furnished me with a list of eighteen land stations fitted on the Marconi system for commercial ship signalling, together with a list of forty-three passenger-steamers already furnished with the Marconi apparatus, thus affording evidence of its application to practical purposes.

The system of "wireless telegraphy" by Sir Oliver Lodge and Dr. Muirhead has, I understand, been fitted to cable steamers of the Eastern Extension Telegraph Company, to enable communication to be made with their cable stations.

SEWAGE DISPOSAL.

The bacterial treatment of sewage is receiving much attention, and by the courtesy of Mr. J. Corbett, M.Inst.C.E., the Borough Engineer of Salford, I am enabled to make a brief reference to the system of sewage treatment now carried on at the Salford Corporation Sewage Works, adjoining the Manchester Ship Canal. Twenty years ago the works were constructed with precipitation tanks for lime treatment of the sewage. After fourteen years of experiments with various precipitation and filtration processes, ten of the original precipitation tanks were formed into two large tanks in which precipitation takes place with the aid of milk of lime and salts of iron. The other two original tanks were converted into six roughing filters containing 3 feet in depth of fine gravel, to intercept particles which have escaped the precipitation process, and which would tend to choke the final filters. The final purification is on bacteria beds or aërated filters, with an open false floor of perforated tiles and large open culverts giving constant ventilation through the beds, some of which are filled to a depth of 5 feet and others to a depth of 8 feet with crushed clinkers of from $\frac{3}{16}$ inch to $\frac{3}{4}$ inch diameter. The liquid is "rained" on to the surface by spray jets, and the beds are used generally in shifts of two hours each for eight hours a day in dry weather and for twenty-four hours during heavy rainfall. An average quantity of from 400 to 500 gallons of sewage per square yard per day is treated with satisfactory results.

LIVERPOOL DOCKS.

Although there may seem little of interest in the vast areas of sand which separate Southport from the sea, yet if the whole sea coast from the Dee to the Ribble be taken into consideration, there are few areas of greater interest to the hydraulic engineer than these rivers with the shores that bound them, and few in which stranger changes in land level have occurred within historic times. In the Itinerary of Ptolemy, the Ribble is named immediately after the Dee, the Mersey being omitted altogether.

At the meeting of this Association at Liverpool in 1896, reference was made to these matters, not only by the President of this Section, Sir Douglas Fox, Past President Inst.C.E., but also in papers read, one of which, by Mr. T. M. Reade, F.G.S., is entitled "Oscillations in the Level of the Land, as shown by the Buried River Valleys and Later Deposits in the neighbourhood of Liverpool."

Evidence of the gradual sinking of the land is given by the very interesting discovery in 1850 of a Roman bridge at Wallasey Pool, Birkenhead. After excavating fourteen feet, the workmen came upon a bridge of solid oak beams, supported in the centre by stone piers and resting at the ends upon the solid rock at the sides of the creek. The length of the bridge was 100 feet and its width 24 feet, and the beams were each 33 feet long, 18 inches wide, and 9 inches thick; there were 36 beams formed into 12 compound beams, each 27 inches in depth. Careful drawings of this bridge were made by Mr. Snow, an engineer employed on the work then in progress. The drawings show that the rocky bed of the stream was some 13 feet below the bridge, which was itself about 16 feet below present high-water level.

Formerly Liverpool was one of the ports subordinate to the Comptroller of Chester, and is styled in the Patent "a creek in that port."

The first Act of Parliament authorising the construction of Dock works was obtained in 1709, and in 1853 the water area of the docks had been increased to 178 acres. Since 1853 the progress has been much more rapid, especially within the last thirty years. The total area of the docks and basins at Liverpool and Birkenhead is now 566 acres, whilst in connection therewith there are rather more than 35 miles of quayage. The marked tendency in recent years to increase the length, beam, and depth of ocean-going steamers has necessitated the provision of dock accommodation for a much larger class of vessel than formerly existed; and during the last decade works of great magnitude have been successfully carried out by the Mersey Docks and Harbour Board, under the able direction of the late Mr. G. F. Lyster, M.Inst.C.E., and, since his death, of his son, Mr. Anthony G. Lyster, M.Inst.C.E. In the northern section a new graving-dock has been constructed, extensive additions have been made to the Canada and Huskisson Docks, whilst the difficult work of constructing new river entrances has also been satisfactorily completed. In the southern section, the Queen's Dock has been enlarged and other important additions have been executed and brought into use.

To convey some idea of the magnitude of the works executed, it may be mentioned that the amount expended by the Dock Board in the extensions above indicated exceeds 1,750,000*l*.

The largest lock connected with the port of Liverpool is the Canada, 600 feet long by 100 feet wide, the sill being 14 feet below the datum of Old Dock sill, which datum is 4 feet 8 inches below Ordnance datum, or mean sea-level. Two large river-entrance locks into the Brunswick Dock are now approaching completion, the larger lock having a length of 350 feet and a width of 100 feet, with a sill 19 feet 6 inches below the datum of Old Dock sill.

One of the striking features in connection with the port of Liverpool is the difficult and extensive work connected with the dredging operations at the Mersey Bar. Since the commencement in 1890, to August, 1903, no less than 72,000,000 tons of material have been dredged and removed from the Bar and sea channels, and the average quantity for the last five years has been in round figures, 7,000,000 tons per annum. The total tonnage of the port for the year ended July 1, 1903, was 13,308,305, and the receipts therefrom amounted to 1,185,066*l*., exclusive of graving dock and other rates.

IRRIGATION.

This being the first Meeting of the British Association since the completion of the Assuan dam, which I had the opportunity to inspect when visiting Egypt in the early part of this year, I should like to devote to it a short portion of my Address. Those who desire to learn all about that work in detail I would refer to the papers (to which, indeed, I am indebted for my information on the subject) read before the Institution of Civil Engineers on January 27 last by Mr. Maurice Fitzmaurice, C.M.G., M.Inst.C.E., who had charge of the work on behalf of the Egyptian Government from its commencement in 1898 until December, 1901, and by Mr. F. W. S. Stokes, M.Inst.C.E.,

managing director of Messrs. Ransomes and Rapier, of Ipswich, who undertook the manufacture and erection of the sluices and lock-gates.

The Nile reservoir has been constructed for the purpose of impounding the water of the River Nile during the winter months, and discharging it in the months of May, June, and July, so as to supplement the ordinary flow of the river, and thus enable land to be irrigated which would otherwise receive either no water, or an insufficient supply. The situation chosen for the dam was the head of the Assuan cataract. There were various reasons for the choice: there was a wide section of the river, the waterway being about seven-eighths of a mile, thus permitting the construction of sufficient sluices at different levels to discharge the whole volume of the Nile in flood without weakening the dam by placing them too close together; the height of the dam would be moderate; the site chosen seemed to promise good rock foundation throughout, and there were several natural channels when the water was low, each of which could be dealt with separately if desired.

Arrangements had to be made to house and feed a population of 15,000; offices, workshops, a hospital, and other temporary buildings had to be erected, and a line of railway about 3 miles in length had to be constructed to connect the railway from Luxor to Assuan with the works at the dam. This preliminary work was carried out in 1898, and on February 12, 1899, H.R.H. the Duke of Connaught laid the foundation-stone of the dam.

To enclose the site of the permanent masonry dam, and to render it dry for the purpose of excavation and laying the masonry, temporary dams, known in Egypt as "sudds," had to be formed both above and below the site of the permanent dam. At low Nile the river at the Assuan cataract divides itself into five channels, and this work was done in five sections. The down stream "sudds" were first made, and consisted of stones. After the rush of water had been thus stopped, the up-stream "sudds" were formed of bags of sand.

It was found that the rock on the site of the dam was decomposed. The importance of a solid rock foundation was paramount, and to obtain it the excavation had to be carried down to a considerable depth, necessitating the removal of double the amount of material which had been contracted for, and the construction of nearly one and a half times the quantity of masonry that had been anticipated. The masonry, consisting of local granite set in Portland cement mortar, was commenced in May, 1900, was carried on vigorously during two working seasons in which the Nile was abnormally low, and was finished in June, 1902, less than $3\frac{1}{2}$ years after the first stone was laid, and one year before the expiration of the contract time. The dam is nearly $1\frac{1}{4}$ miles in length, and the difference between the surface of the water on the up-stream side and that on down-stream side is $65\frac{1}{2}$ feet when the reservoir is full. The masonry is pierced by 180 sluices, of which 140 are 23 feet high by 6 feet $6\frac{3}{4}$ inches wide and 40 are 11 feet 6 inches high by 6 feet $6\frac{3}{4}$ inches wide.

The construction of the dam having closed the river to navigation, provision for the passage of vessels was made by means of a canal formed on the west bank of the Nile and having a succession of four locks.

The capacity of the Nile reservoir when filled to the top water height of 348 feet above mean sea level is about 37,600 million cubic feet, a quantity which might have been greatly increased had not the desire to preserve the Temple of Philæ prevented the raising of the water to the level originally proposed. Even now many portions of the temple or its adjacent buildings are partially submerged.

It is anticipated that by allowing the whole volume of the Nile to pass through the sluices when most laden with mud during floods, the silting up of the reservoir to any considerable extent will be prevented. The cost of the works was nearly 2,450,000*l.* or about 10*l.* per million gallons of water impounded.

The original surveys and designs for the works were prepared by Mr. Willcocks (now Sir William Willcocks, K.C.M.G.), under the instructions of Lord Cromer and Sir William Garstin, Sir Benjamin Baker, K.C.B., K.C.M.G., F.R.S., Past President Inst.C.E., being the consulting engineer. On the retirement of Mr. Fitzmaurice, he was succeeded by Mr. C. R. May, M.Inst.C.E., as engineer in charge. The work was carried out by Messrs. John Aird and Co., as contractors, Mr. John A. C. Blue, Assoc.M.Inst.C.E., acting as their agent.

All concerned in the inception and execution of this great undertaking are to be congratulated on its successful and speedy completion, in the face of the many difficulties which were encountered and overcome.

WATER SUPPLY.

To everyone a plentiful supply of good water is not only a luxury, but almost a necessity of existence, yet how few even amongst the more intelligent of the millions who are accustomed to find such a supply ready to hand at the nearest tap have more than a very imperfect notion of the works that have to be constructed to obtain it, or the daily care and attention given to secure and maintain its purity, to ensure its efficient distribution, and to prevent its waste by careless, ignorant, or reckless consumers. It may therefore not be out of place that when the chair of this Section of the British Association happens, as now, to be occupied by one whose professional life has been largely associated with waterworks undertakings, he should address you on that subject, and endeavour briefly to direct attention to some of the main features of waterworks construction and management. In following that course I shall, however, necessarily have to describe what is already well known to at least a portion of my audience, on whose indulgence I must therefore rely.

Water supplies may be divided into two main classes, namely, "Gravitation" and "Pumping." In some instances a combination of gravitaiton and pumping is resorted to, especially in those cases in which the more elevated portions of the district to be supplied are situate above the gravitation level. In selecting a suitable source of supply the main points for consideration are the *quantity* and the *quality* of the water. The quantity should be such as will not only suffice to meet the requirements throughout the most protracted periods of drought and frost of the existing population to be served, but should provide for the probable growth of that population during a reasonable number of years to come. The quality of the water selected should be the best that can be obtained, having due regard to considerations of expense. The question of the altitude being sufficient to permit of a supply by gravitation is of far less moment than those of quantity and quality, because the difference in cost between water derived by gravitation and that obtained by pumping is, in the United Kingdom, less than is generally supposed; indeed, contrary to popular belief, gravitation water is frequently more costly than pumped water, owing to the much greater capital outlay usually incurred in the construction of the works for storing and conveying it.

Gravitation works may be divided into three classes, namely, those in which water is taken directly from a spring or stream without storage, those in which it is taken from a natural lake, in which case the surface level of the water is usually raised so as to increase the capacity of the lake as at Thirlmere, and those more numerous cases in which the water of a spring is impounded in an artificial reservoir generally formed by the construction of an earthen or masonry dam across the valley along which flows the stream to be taken.

In the more populated portions of England it is becoming more and more difficult to find an unappropriated gathering ground available as a source of water supply. The gathering ground, or drainage area as it is frequently termed, should either be free from human habitations and other sources of possible pollution, or any pollution arising therefrom should be capable of being efficiently disposed of by removal from the area of the gathering ground or otherwise.

The gathering ground must also possess a site suitable for the formation of an impounding reservoir. When this has been selected it next becomes necessary to ascertain the amount of the available rainfall, as recorded by rain-gauges situate in the drainage area or its immediate vicinity, or where these are not available, as deduced from the returns obtained from more distant rain-gauges, care being always taken that some at least of the gauges have been observed for a sufficient number of years to enable the true average rainfall to be determined. To store the whole of the water flowing from a gathering ground during a cycle of wet years in order to utilise it during a cycle of dry years would

entail the construction of reservoirs of enormous capacity, at a cost incommensurate with the object to be attained; it is therefore customary to make them of such size as to enable the supply to be maintained without risk of failure throughout the three driest consecutive years, the mean annual rainfall of which years generally amounts to about four-fifths of the average taken over a long period—say, forty or fifty years. From the mean rainfall of the three driest consecutive years a deduction must be made for loss by evaporation, which is usually between twelve and sixteen inches. The result is known as the available rainfall, and represents the quantity of water which can be drawn continuously from an impounding reservoir without fear of failure in the driest years. But the whole of this water can rarely be abstracted from a stream without injuriously affecting mill-owners or other riparian owners on the stream below the reservoir; therefore they have to be compensated for the injury they sustain. This is sometimes done by payments in money, but where the mills on the stream are numerous it is generally more economical to make compensation in water delivered into the stream immediately below the reservoir, because the same water compensates each mill in succession as it flows down the stream.

It has now become an accepted principle that one-third of the available rainfall flowing down a stream in a regulated quantity day by day throughout the year is of greater benefit to the mill-owners (with a few exceptions) than the whole of the rainfall allowed to flow in the irregular manner in which it is provided by nature. This compensation water is discharged from the reservoir into the stream either during certain hours on working days or by a uniform flow throughout the twenty-four hours of every day; a method now frequently demanded by County Councils on so-called sanitary grounds, but which is in my opinion not infrequently detrimental to the interests of mill-owners without a corresponding advantage to the public.

Where compensation in water is given there remains for distribution in the district to be supplied a quantity equal to only two-thirds of the *available* rainfall.

Assume for the sake of illustration a case in which the gross annual rainfall is 40 inches. Then we have:—

	Inches
Gross annual rainfall	40
Deduct to arrive at the mean annual rainfall of the three driest consecutive years—say one-fifth of forty	8
Mean annual rainfall of three driest consecutive years	32
Deduct for evaporation, say	14
Available for supply if no compensation water be given	18
Or if compensation water be given *deduct* one-third	6
Leaving available for supply	12

Having now ascertained the amount of the rainfall available for the supply of the district, it remains to be seen whether or not the area of the gathering ground above the reservoir is sufficient to give the required quantity of water. If it is not, the area may in some cases be extended by means of catch-waters in the form of open conduits cut along the sides of the valley below the embankment of the reservoir, and at such an elevation as will enable them to discharge the waters they collect into the reservoir above its top water line.

Almost all waters derived from gathering grounds are much improved by filtration before use for potable purposes. In some cities and towns in this country, more especially in Lancashire and Yorkshire, the benefit derived from filtration has not been sufficiently appreciated, and the water is still delivered into the houses unfiltered; but I am of opinion that the time will come when nearly every town of importance supplied with water derived from gathering grounds will adopt filtration, for it not only removes matters in suspension but it also diminishes the discoloration due to peat which is to be found in most moorland waters.

Reservoir dams in Great Britain consist either of earthen embankments or masonry walls. Of the former, examples of considerable size may be seen at the reservoirs of the Manchester Waterworks, designed by Mr. J. F. Bateman, F.R.S., Past President Inst.C.E., who was President of Section G of the British Association at the Manchester Meeting in 1861; and at the Rivington reservoirs of the Liverpool Waterworks, designed by my father, the late Mr. Thomas Hawksley, F.R.S., Past President Inst.C.E., who was President of this Section at the Meeting at Nottingham in 1866.

Earthen embankments are formed of the most suitable materials to be obtained by excavation in their neighbourhood; the water is retained by a wall of watertight clay puddle forming the core of the embankment, extending for its whole length and continued at each end into the natural ground forming the hillsides. This puddle core has to be carried down into the ground until watertight strata be met with, occasionally necessitating a puddle trench having a depth of 80 feet or more below the bottom of the valley and 200 feet or more in depth in the hillsides. Where the strata forming the sides of the valley are not watertight, it is necessary to continue the puddle core along the sides of the reservoir by means of wing trenches. The determination of the depth and extent of the puddle trench in order to secure the watertightness of the reservoir is one of the most difficult and anxious duties of the engineer on whom rests the responsibility of its construction. In forming his judgment he has to rely entirely on his experience for guidance, this being one of those matters which cannot be learnt at an engineering school or even in an engineer's office. How much depends on the exercise of a wise and trained judgment may be understood when it is realised that an error in this respect may result in very costly works having subsequently to be undertaken to stop an escape of water which might in the first instance have been prevented by a comparatively small outlay.

Provision has to be made for the passage of flood-waters during the construction of the embankment. This is ordinarily effected by the construction at about the level of the stream of a tunnel of sufficient diameter to convey with only a slight head the volume of water produced by the greatest flood which experience has taught us to anticipate. This tunnel is sometimes formed beneath the embankment, but preferably, where the circumstances are favourable, it is carried through the natural ground near to one end of the embankment. A shaft is built in connection with the tunnel, in which, after the embankment has reached its full height, are placed the outlet valves of the reservoir.

It is of the utmost importance that ample provision should be made for carrying off the flood and other surplus waters coming from the gathering ground when the reservoir is full, for if this be not done serious consequences may ensue, including the washing away of the embankment with resulting destruction of property and even of life. The surplus waters sometimes fall down a shaft erected within the reservoir, and make their escape by means of the tunnel previously mentioned, but more frequently they flow over a masonry weir and reach the stream below the embankment by means of a bye wash formed in the hillside. In my opinion the latter method is in most cases to be preferred, as being free from the risk of blockage by ice to which the shaft and tunnel are liable. Engineers are occasionally reproached with extravagance in the magnitude of the provision made for the escape of flood waters, but it must always be borne in mind that a *maximum* flood has to be provided for, such a flood as may occur only once in twenty or thirty years, but which must find a means of escape when it does occur, without danger to life or property.

Masonry dams are not so frequent in this country as earthen dams, partly by reason of their greater cost and partly because the geological conditions are generally not favourable to their formation, for not only do they require a supply of suitable stone near to hand for their construction, but they also need an incompressible foundation such as rock or very strong shale. Any irregularity in the compression of the foundation occasioned by the weight of the dam would be liable to fracture the masonry of which it was built.

In the case of masonry dams a tunnel for the passage of flood waters during construction is formed at a suitable level in the masonry of the dam, and after completion of the work they are generally allowed to pass over the top

of the dam for the whole or a portion of its length, thus obviating the necessity for and the cost of an independent bye wash.

Whilst masonry dams have the advantage over earthen dams of not being liable to be breached by a waterspout, I am not aware of any case in which an earthen dam has been destroyed in that manner, and so far as I am able to form an opinion the accidents due to other causes have been as frequent in the case of masonry dams as in that of earthen dams. The destruction of masonry dams has in some instances been the result of too great reliance having been placed on theoretical calculations, without sufficient allowance having been made for the many defects in material and workmanship which might occur in a work of that kind. It was the opinion of the late Mr. Thomas Hawksley that in some cases the destruction of masonry dams had been occasioned by the neglect of the effects of uplift due to the pressure exerted by water finding its way beneath the bottom of the dam, a possible condition which he was very careful to take into account when designing the masonry dam of the Vyrnwy reservoir of the Liverpool Waterworks.

Examples of large masonry dams in the United Kingdom may be seen in that constructed by Mr. G. H. Hill at Thirlmere Lake, from which the city of Manchester is partly supplied with water. Also at the Vyrnwy reservoir of the Liverpool Corporation Waterworks, designed by and partially carried out under the direction of the late Mr. Thomas Hawksley, after whose retirement it was completed by Mr. G. F. Deacon, who presided over Section G on the occasion of the visit of the British Association to Toronto in 1897; and again at the reservoirs near Rhayader, in Wales, now approaching completion, from the designs and under the direction of Mr. James Mansergh, F.R.S., Past President Inst.C.E., for the supply of water to the city of Birmingham.

From the impounding reservoir the water has to be conveyed to the point of distribution by an aqueduct. This aqueduct, which is sometimes of great length, may consist either wholly of metal pipes, usually of cast iron, or partly of a conduit constructed of masonry, brickwork or concrete following the contour of the ground, with occasional tunnels where high ground has to be passed through, and metal (inverted syphon) pipes where valleys have to be crossed. These conduits may be either open or covered, the latter method being generally adopted, when they become what is technically known as "cut and cover" conduits. In the case of a continuous pipe-line of considerable length it is divided into sections by means of break-pressure tanks interposed at suitable elevations, each tank being say 100 feet or thereabouts below the preceding tank, by which means the pipes are relieved from the excessive pressure to which they would be subjected if the head due to the elevation of the impounding reservoir was carried forward to the service reservoir, from which the water is distributed to the consumer. Steel pipes are frequently used abroad where the cost of carriage is great, but they have not yet been much employed in this country, sufficient experience not having yet been gained in reference to the deterioration of steel pipes due to the action of the water from within and of the ground in which they are laid from without.

The lines of pipe are provided at intervals with suitable stopcocks, sluice-valves, and air-valves, and also in some cases with self-acting valves which close automatically in the event of the velocity of the water in the pipe becoming abnormally increased owing to the bursting of a pipe beyond.

I have already stated that most waters obtained from gathering grounds are much improved by filtration. The process of filtration may be carried on where the water leaves the impounding reservoir or at any convenient point on the line of conduit thence to the place of distribution, provided the filter-beds are situate at such an elevation as to place them on the line of hydraulic gradient. Various considerations will influence the determination of their position, but it is desirable that the water should not be subjected to long exposure to light after filtration. Filtration by the slow passage of the water through a bed of sand from two to three feet in thickness, supported by small gravel or other suitable material, is the method usually adopted in Europe, though what is known as mechanical filtration has been used to a considerable extent in the United States, and may under certain conditions be usefully employed. However I do not think it is likely to take the place to any considerable extent in this country of the efficient system of sand-filtration introduced so long ago as the year 1828 by the late Mr. James Simpson, Past President of the Institution of Civil Engineers. The rate of filtration, to be thoroughly effective, must depend on the condition of the water to be filtered, but a rate of from 450 to 550 gallons per square yard of surface of sand per day (*i.e.* twenty-four hours) is usually found to be efficient. Filter-beds are generally open to the sky, but occasionally, when situate at considerable elevations, they are covered by roofs to prevent interruption by the formation of ice in times of severe frost. In certain exceptional cases in which the water is difficult to treat it is twice filtered with excellent results. The water after filtration should be discharged into a pure-water tank or service reservoir of sufficient capacity to enable the process of filtration to proceed at a uniform rate by night as well as by day, without regard to irregularities in the rate of demand in the district of supply.

The particles in suspension in the water, which are intercepted by the process of filtration, gradually form a film over the surface of the sand, and thus improve the filtration; but this film at last becomes so thick as unduly to reduce the rate at which the water passes through the sand. The filter-bed is then laid off and, the water having been withdrawn, the surface of the sand is scraped off to a depth of about a quarter of an inch; the sand thus removed is washed in suitable machines to free it from the matter intercepted during the process of filtration, and is afterwards replaced in the filter-bed either immediately or after several similar scrapings have taken place, care being taken that the thickness of the sand left in the bed shall not at any time be reduced below that required to ensure efficient filtration. From time to time the sand is removed to a depth of several inches and washed, and occasionally it is taken out and washed to its full depth. From the foregoing description it will be understood that the filtration of water, although a simple process, is one which necessitates constant watchfulness on the part of those responsible for the management of those waterworks undertakings in which the water undergoes filtration.

As near to the termination of the aqueduct conveying the water from the impounding reservoir to the point of distribution as the levels of the ground will permit, a service reservoir should be constructed for the purpose of equalising the flow of water along the aqueduct, and for maintaining the supply to the district during any temporary interruption on the line of aqueduct due to a burst pipe or otherwise. The service reservoir should contain not less than one day's supply, two or three days, and, in exceptional cases, even more being sometimes desirable. Service reservoirs should by preference be covered so as to exclude light, and thus prevent the growth of vegetation which would otherwise take place. The covering, when consisting of brick arches, has also the advantage of keeping the water cool in summer, and preventing the temperature from becoming too much reduced in winter. The rate of draught on the service reservoir is continually varying throughout the day and night according to the hourly requirements of the population which it serves. This variation is very considerable, amounting during certain hours of the day to at least twice the average rate of consumption during the twenty-four hours. It will therefore be apparent that were it not for the equalising effect of the service reservoir the aqueduct must have a capacity at least double that which is needful where a service reservoir is available. At Southport, for example, although the water is distributed from a service reservoir, that reservoir is situate at a distance of about seven miles from the town, because, owing to the great extent of comparatively flat land in the neighbourhood of Southport, it was impossible to obtain a suitable elevation nearer to the town than Gorse Hill, on the summit of which the reservoir stands. Consequently the main pipes thence to the town have to be of sufficient capacity to convey the water at a rate corresponding with the demand at the time of *maximum* consumption, or, in other words, of about twice the capacity which would have been needed if the service reservoir could have been placed close to the town, when these pipes would, for the greater part of their length,

have been situate on the inlet instead of on the outlet side of the reservoir.

Having now followed the water in the case of a gravitation supply from its source to the service reservoir from which it is to be distributed to the consumers, it will be convenient to follow in a similar manner water obtained by means of pumping, leaving until later the consideration of its distribution, which, after it leaves the service reservoir, is common to both gravitation and pumped water.

Pumping supplies may be divided into two sections—first, those where the water is drawn from a source only slightly below the level of the pumping engines, such as where the water is taken from a stream or lake, or from culverts formed in gravel beds, or is discharged from impounding reservoirs situate at too low a level to enable the water to gravitate to the point of distribution; and secondly, where the water is raised from deep wells sunk in the sandstone, chalk, or other water-bearing strata.

In the first-mentioned cases the water has usually to be filtered, when it is generally found convenient to place the filter-beds at the pumping station, the water being firstly lifted (unless it will gravitate) on to the filter-beds, and secondly, after filtration, and by means of a separate pump, forced through pipes up to the service reservoir whence it is to be distributed.

In the case of deep wells, the water seldom, if ever, requires filtration, and is usually raised either directly or through pipes into the service reservoir, the total lift being frequently divided between lift pumps and force pumps with the object of balancing the work to be done by the engine.

Sometimes the well alone will yield a sufficient supply of water, but often it has to be aided by boreholes or by drifts or headings driven horizontally in the water-bearing strata near the level of the bottom of the well, and occasionally continued for a considerable distance, even as much as a mile or more from the well, the length of the headings depending on the quantity of water which can be profitably obtained from them, and also on other considerations too various to be mentioned here. There are cases in which it is possible to obtain sufficient water by boring from the surface of the ground and lowering a pump down the bore hole. The expense of a large well is thus saved, but it is, of course, impossible to augment the supply by drifting.

The time at my disposal will not admit of any observations on the merits of the various kinds of engines and pumps employed in raising water; they are not only very numerous, but each has to be considered in relation to its suitability for the particular circumstances of the case in question. Suffice it to say that, although most of the water pumped in the United Kingdom is raised by means of steam engines, water turbines, gas engines, oil engines, and (to some slight extent) electric motors are also employed. It may be mentioned that one of the largest oil engines in this country is engaged in pumping water from a deep well, and it is not improbable that gas and oil engines will in the future become more largely employed for waterworks purposes.

It should here be mentioned that there are a few instances in this country, and many in the United States of America, in which a service reservoir is dispensed with, and water is pumped directly into the main and distributing pipes of the district to be served, a method which, although employed with success, should not, in my opinion, be adopted where the circumstances admit of the use of a service reservoir. Where direct pumping is used, provision must be made to ensure continuous pumping day and night without intermission, so as to avoid interruption to the supply of the district, and the speed of the engines must be constantly varied to meet the demands of the consumers for the moment. The maintenance of uniformity of pressure in the main pipes may be assisted by the employment of large air vessels, or by accumulators such as are used for the supply of hydraulic pressure, or preferably by a combination of air vessels and accumulators.

We will now return to the service reservoir. When this reservoir is situate between the source of supply and the district to be supplied, it receives the whole of the water and delivers it into the district as needed for use; but when the district lies between the source and the service reservoir, it receives the excess of supply over consumption, and on the other hand makes good any deficiency during those hours when the consumption exceeds the supply. In either case this reservoir has the effect of equalising the flow from the source to the reservoir throughout the twenty-four hours of the day.

From the service reservoir the water is conveyed by one or more main pipes into the district of supply. These pipes are gradually reduced in diameter as they pass through the district, the water which they convey is taken off by other main pipes branching from them, and finally enters the service pipes, which are usually from five inches to three inches diameter, and are those from which the consumers' communication pipes are taken. The service pipes should in all cases be controlled by valves, so that the water can be shut off from them without interfering with the flow through the main pipes. Consumers' communication pipes are not generally allowed to be attached to pipes of greater diameter than five inches, and where a pipe of six inches diameter and upwards is carried along a street, another pipe of three or four inches diameter (preferably the latter size), and called a ryder pipe, is laid alongside to receive the attachments of the communication pipes. The ryder pipe is divided into lengths of from 350 to 400 yards, each of which is controlled by a valve at its junction with the main pipe. Hydrants for use in case of fire are attached to the ryder and other service pipes throughout the district at a distance apart not exceeding 100 yards. Except in streets where the houses are small and not high, it is desirable to lay the service pipes of not less than four inches diameter, not because a smaller pipe would not suffice to meet the requirements of the domestic consumers, but in order to ensure an ample supply of water in case of fire. When determining the sizes of the main pipes to be laid throughout a town, the engineer commences with the pipes most remote from the service reservoir, and gradually increases the diameter according to the probable number and magnitude of the supplies to be taken from them.

Pipes of cast iron having sockets run with lead and set up with a hammer are mostly used for waterworks purposes, but in some instances turned and bored joints put together without lead have been used with success, but these are only suitable where there is an unyielding foundation. I remember a case in Yorkshire, where turned and bored pipes were, much against the advice of the engineer, used for the distribution of gas in a colliery district, with the result that in a few years nearly every joint was leaking; fortunately the engineer had anticipated that result, and had laid the pipes with sockets in addition to the turned and bored joints; consequently, by opening the ground at each joint and running the joint with lead, the leakage was stopped without necessitating the relaying of the system of pipes. The main pipe of forty-four inches diameter, conveying water from Rivington to Liverpool, passes for several miles over a coalfield, and the ground has in places subsided over the coal workings as much as four feet without interfering with the supply of water; the ground having been opened at the pipe joints, the lead, which had been partially drawn from the joints, was forced back by hammering, and the joint was again made sound.

In some countries, where the cold is intense, water pipes have to be laid at a depth of from 10 feet to 12 feet below the surface of the ground to protect the water from frost, but in the United Kingdom a depth of from 2 feet 6 inches to 3 feet has been found to be sufficient even in very severe frosts.

Water, especially when soft, causes the interior of cast-iron pipes to become incrusted with nodules of iron, which reduce the effective diameter of the pipe and so diminish its capacity. This action is greatly retarded and in some instances entirely prevented by the application to the pipes, soon after they have been cast, of the coating introduced many years ago by the late Dr. Angus Smith, a process now nearly always employed.

It was at Southport that I witnessed the bursting of a main pipe, the only occurrence of the kind that I have seen during a period of forty years, of which a considerable portion has been spent amongst waterworks. Owing to the introduction of a new supply of water, the original main pipe was charged with water at a higher pressure than it had been intended to bear, with the result that several fractures occurred. I happened to be standing on one of

the roads at a little distance from the town when I heard a sound, and looking in the direction whence it came, saw in a field near by a black column rise vertically in the air for about forty feet in height. A girl who happened to be working in the field put her hands to her ears and fled, probably thinking she had seen Satan himself, but the column soon became clear, the black colour having been caused by the peat carried up with the water.

Having traced the water from its source to the door of the consumer, we now enter into another branch of the subject. Up to this point the water has been entirely under the control of the company or local authority by whom it is provided, but from the moment it enters the consumer's communication pipe, or where the communication pipe is the property of the water supplier, from the moment the water reaches the premises of the consumer, it comes under his control, subject only to such regulations and supervision as the Legislature has given the water supplier power to make and to exercise.

When water was supplied on the now almost obsolete "intermittent service," under which a town was divided into a number of districts into each of which in succession the water was turned for only one or two hours a day, the water suppliers paid but little attention to the fittings within the houses of the consumers, because, however great the quantity of water wasted through defective fittings, the waste could only last for the short time during which the water was turned on in each district, and it ceased altogether during the night.

About the year 1831 the system of "constant service," by which is meant a supply of water available from the pipes of the water suppliers at any moment throughout the day or night, was introduced into this country by the late Mr. Thomas Hawksley, at Nottingham, and it soon became evident that if a constant service was to be maintained the fittings within the houses of the consumers must be adapted to the new conditions and be placed under regulation and supervision. Suitable regulations were therefore formulated, and have since been improved and modified to meet modern requirements. These regulations, which are mainly directed to the use of proper pipes, taps and other fittings, and to service cisterns so constructed as to prevent a continuous flow and consequent waste of water, do not in any way limit the use of water by a consumer, who is at liberty to take as much as he requires whether by day or by night, nor does their strict enforcement inflict any hardship on the consumer, to whom good water fittings kept in a proper state of repair are in the end more economical than cheaper and inferior fittings requiring the frequent attendance of the plumber.

About five years ago, I had occasion to obtain statistics relating to the consumption of water in sixteen towns (including Southport) in England, containing an aggregate population within the district supplied of rather more than five millions of people, and found that the average quantity of water consumed in those towns for domestic purposes was 18½ gallons per head per diem, showing what can be effected by good management and a careful observance of proper regulations for the prevention of waste without imposing any restriction on the quantity of water legitimately used. The figures which I have quoted as water for domestic purposes include the unmetered trade supplies and that comparatively small amount of waste which cannot be prevented, but do not include the water supplied by meter for trade purposes, the amount of which varies greatly in different towns, but being paid for by the consumer according to the quantity used may be disregarded when comparing the management of waterworks undertakings.

Some soft waters, more especially those derived from moorlands, have an injurious action on lead pipes and lead-lined cisterns, and are liable to cause lead poisoning in sensitive persons drinking the water, but this action is now commonly prevented by bringing the water into contact with lime before distribution.

In certain instances of public supplies, the hardness of the water is reduced by one of the several softening processes now in use, but it more frequently happens that the softening is effected by those consumers who require soft water for boiler or other trade purposes.

A few words with regard to the water supply of the town in which the Meeting of the British Association is now being held may not be out of place, the more especially when it is borne in mind that the rapid growth of its population during the last half century could not have taken place but for the introduction of a supply of good water.

The Southport Waterworks Company, by whom water was originally brought to Southport, was established under the authority of an Act of Parliament passed in the year 1854. Water was first obtained from a well sunk at Scarisbrick, about five miles south-east of Southport, a source which was practically superseded by another well which was a few years later sunk at the Aughton pumping station near Ormskirk. As the population to be supplied increased in numbers, the Company subsequently sank a third well, and constructed the still larger Springfield pumping station near Town Green, about nine miles south-east of Southport, and it is from the Aughton and Springfield wells, both sunk into the Bunter Beds of the New Red Sandstone formation, that the present excellent supply of water is derived. At each pumping station the water is raised by a pair of beam rotative steam-engines into two covered service reservoirs situate on the summit of Gorse Hill, near Ormskirk, at an elevation of 260 feet above ordnance datum, or in other words, above the mean level of the sea. From this reservoir the water is brought through two main pipes to Southport and Birkdale, which places have from the commencement of the undertaking had the advantage of a constant service. The late Mr. Thomas Hawksley acted as engineer to the company from its formation until his death in 1893, and I subsequently acted in that capacity until the transfer, under the powers of the Southport Water (Transfer) Act, 1901, of the undertaking of the company to the Southport, Birkdale, and West Lancashire Water Board, consisting of representatives of the Corporation of Southport, the Urban District Council of Birkdale, and the Rural District Council of West Lancashire.

The advances in recent years in chemical science, and the application of the science of bacteriology to the examination of water, have led to the condemnation of waters which a few years ago would have been deemed to be perfectly suitable for a town supply. Whilst fully appreciating the advantages to be derived from the most careful examination of water supplied for domestic consumption, I cannot but think that we are sometimes unnecessarily alarmed by the results obtained. Taking a broad view of the subject, and looking to the healthy condition of towns which have for many years been supplied with water from sources now regarded with suspicion, I venture to think that the teachings of chemistry and bacteriology are as yet but imperfectly understood, and that in the future it will be found that some waters now considered of doubtful character are perfectly good and wholesome. I am well aware that the expression of these views may call forth the indignation of some of my friends amongst eminent chemists and bacteriologists to whose opinions on such subjects I feel bound to pay deference. A Royal Commission has recently recommended that a Government department be established and endowed with enormous powers of interference with the action and discretion of the bodies entrusted by Parliament with the responsibility of the administration of water supplies, and it behoves those bodies to give careful consideration to that recommendation, and to take such steps as may be necessary to check any attempt to give effect to a proposal which may result in committing them to the carrying out of unreasonable requirements, possibly involving needless expenditure, at the bidding of a Department from whose dictum they may have no appeal.

Although a matter only indirectly connected with water supply, I think it may be of scientific interest to this Section to have brought to their notice the case of the River Rede in Northumberland, which takes its rise in the Cheviots. At a place called Catcleugh, about four miles below the source of the Rede, its waters are diverted by the Newcastle and Gateshead Water Company for the supply of their district. The gathering-ground above the point of diversion is about 10,000 acres in extent, and the quantity of water taken is ascertained by means of a gauge, and registered continuously by a recording instrument. An inspection of the diagrams taken during periods in which there was no rainfall shows a daily variation in the volume of water flowing down the river. For example, during a period of eight days (June 9 to 16, 1899) without interruption by rain,

the gradual rise and fall of the river was almost regular, day by day, the maximum flow occurring about 9 a.m., and the minimum about 9 p.m., the difference between the two amounting to nearly 10 per cent. of the total quantity passing down the river at the time of minimum flow. Various suggestions as to the cause of this phenomenon have been made, but I am unable to give any satisfactory explanation. It occurs in winter as well as in summer, and may take place daily throughout the year, though it cannot be observed except during dry periods. It may well be that a similar phenomenon occurs in other rivers, but has escaped observation owing to the absence of recording gauges.

THE INTERNATIONAL GEOLOGICAL CONGRESS.

THE ninth gathering of the International Geological Congress was held this year in Vienna. After a preliminary series of excursions through different parts of Austria-Hungary the members assembled in the rooms of the University on Thursday, August 20, when the meeting was inaugurated by the Archduke Rainer and the Minister of Public Instruction. According to the programme prepared by the committee of organisation, each alternate day was to be devoted to the reading and discussion of papers on given subjects of general interest, while the intervening days were given up to excursions in the neighbourhood of the imperial city. After the formal opening of the congress, the afternoon of the first day was spent, under the presidency of Mr. Emmons, of the United States Geological Survey, in receiving a miscellaneous group of communications, including a paper on the Laccolites of the Aar-massif by Prof. Baltzer, and an account of the recent volcanic eruptions of Martinique and St. Vincent by Mr. E. O. Hovey, illustrated by an excellent series of photographic lantern slides. The next day of discussion (August 22) was dedicated to the crystalline schists, under the chairmanship of Prof. Zirkel in the morning and Prof. Loewinson-Lessing in the afternoon. Until the various communications are in print and can be studied and compared, it is hardly possible to say how far they have advanced our knowledge of the subject. The speakers on this and subsequently on the other selected subjects of discussion showed a prevailing tendency to dwell on the local peculiarities of the regions most familiar to them, and rather to lose sight of the general principles to which local observations should properly lead. The crystalline schists of Germany, Austria, the Alps, Finland and North America were all brought into review, so that a sufficiently wide basis was provided for satisfactory generalisation. The third day (August 24) for the reading of papers, under the presidency of Sir Archibald Geikie in the forenoon and Prof. Heim in the afternoon, was spent in listening to essays by various geologists on the important phenomena embraced under the general designation of "overthrusts." MM. Lugeon and Haug described the structures displayed in the Alps, Prof. Uhlig those of the Carpathians, Mr. Bailey Willis those of the United States. In an interesting discussion Prof. Heim indicated that he surrendered the so-called "double-fold" of the Glärnish, as originally advocated by him, and now admitted that the structure implied a gigantic overthrust. Prof. Rothpletz, who has long maintained this view, also took part in the debate, which at times became lively from the energy of the speakers and the difficulty which they found in confining their exuberance within the limits of time prescribed by the council. Though the doctrine of overthrusts was admitted, considerable divergence of opinion appeared as to the true nature and origin of the structure.

Wednesday (August 26) was dedicated to a consideration of the geology of the Balkan peninsula and the East, under the presidency of Prof. Barrois in the forenoon and Prof. Tschernyschew in the afternoon. An interesting and important series of papers was read, in which the present state of our knowledge of these regions was detailed by those geologists to whom the recent advance of that knowledge has mainly been due.

On Thursday (August 27) the morning was taken up in the reception of miscellaneous communications in four different rooms of the University. As this extensive building includes a large number of rooms separated from each other by staircases and passages, and as no adequate system of placards was adopted to guide the members to these various meeting-places, much time was lost in trying to find them, and in some instances the search was abandoned in despair. The afternoon was devoted first to the reception of the reports of the various Commissions appointed by the congress at previous meetings. A satisfactory statement was made by Prof. Beyschlag as to the progress of the international geological map of Europe. Sir Archibald Geikie gave in the report of the Commission on lines of raised beach in the northern hemisphere and also that of the Commission on international cooperation in geological research. On his proposal it was agreed to form a small committee for the purpose of collecting information from different countries with a view to combined effort in those branches of inquiry which are not purely geological but require the services of other sciences. The first number of the "Palæontologia Universalis" was laid before the meeting by M. Oehlert, who was warmly congratulated on the successful launching of this enterprise. The report of the Commission on glaciers was presented by M. Finsterwalder. The recommendation of the committee appointed to consider the Spendiaroff prize was unanimously adopted, that the prize should be awarded to Prof. Brögger, of Christiania. The last official act of the congress was to choose the next place of meeting, which, by a majority, was fixed to be Mexico.

A very unpleasant impression was made on a number of members of the congress by the action of the Vienna committee of organisation in regard to the next meeting place. So far back as March last the general secretary wrote to Dr. Bell, acting director of the Geological Survey of Canada, asking whether an invitation could be sent from Canada to hold the next meeting of congress there, and assuring him that many Austrian geologists would be very pleased to visit that country and would be happy to support the invitation at the approaching Vienna meeting. No mention was made in that letter, or in any subsequent communication, that applications had been sent to any other country. Dr. Bell replied in the same month of March that he cordially welcomed the proposal and would do all in his power to further its acceptance. The Geological Survey and the Royal Society of Canada warmly supported it, and eventually the Government authorities took it up and Parliament actually voted 25,000 dollars towards the necessary expenses of the meeting. Dr. Bell was commissioned to proceed to Vienna and personally invite the congress to hold their next session in Canada. On arriving in Vienna, however, he found that, unknown to any one in Canada, the committee had also been simultaneously in treaty with Mexico, and without writing to know what was being done in Canada had inserted in the official programme an invitation which had in response been received from Mexico. He soon saw that though the committee could not bind the congress, they had practically decided the question in favour of Mexico so far as their votes and influence could go. The Canadian authorities naturally feel indignant at such treatment, and it will excite no surprise if they are in no hurry to renew their invitation should the visit to Mexico fail of accomplishment.

Excursions have always formed a prominent part of the work of the geological congress, and this year they have been organised on a greater scale than ever before. Not only was there a diversified series set on foot before the meeting and another after it, but half the time of the congress in Vienna was devoted to excursions in the neighbourhood. Whether these miscellaneous parties contribute as much as might be desired to the enlargement of the geological experience and knowledge of the congressists, they at least have one excellent result inasmuch as they bring together scientific friends who have seldom a chance of meeting each other and, likewise, enable them to make the personal acquaintance of men with whose writings they may have been long familiar. Indeed, it may be asserted that the fostering of such personal acquaintance is perhaps the most practically valuable part of the work of the congress. For the enlightenment of the excursionists an admirable Livret Guide to Austrian geology was drawn up by Dr. Teller. Of this publication an account will be given in another issue of NATURE.